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RICOCHET AND PENETRATION OF STEEL SPHERES IMPACTING ALUMINUM TARGETS

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February 1983

US ARMY ARMAMENT RESEARCH AND DEVELOPMENT COMMAND
BALLISTIC RESEARCH LABORATORY
ABERDEEN PROVING GROUND, MARYLAND

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A test program was conducted to obtain a complete set of penetration data for steel spheres impacting aluminum targets. The striking speed varied in the range of 100 - 1800 meters/second for two sphere diameters (0.635 and 1.191 cm.), three impact angles (0, 45 and 60 degrees) and three plate thicknesses (0.635, 1.270 and 5.08 or 7.62 cm.). Exit velocity was obtained for the ricochet and the complete penetration regions and the embedment region was determined. Various parameters are tabulated such as crater size, hole size and depth of penetration.

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I. INTRODUCTION

The Ballistics Research Laboratory (BRL) has the primary responsibility for evaluating the vulnerability of US Army's weapon systems under all known enemy threats. In this regard, the most serious damage mechanism is fragment impacts on internal components where the fragments originate from direct fire munition penetration of thick protective armor of surface vehicles or from fragmenting warheads which are capable of penetrating thin protective armor such as that which exist on aircraft. Since individual components are generally enclosed in thin metal casings, knowledge of the penetration capability of fragments through these metals is essential for evaluating individual component damage. In general, the number of possible combinations of those parameters which specify a particular fragment versus target plate interaction is much too large to perform all of the experiments necessary to generate the corresponding penetration data for every situation of interest. Consequently, an effort is being made to formulate analytic models of the penetrator/target interaction. A model which predicts residual speed is described in BRL MR 2797.[1] A more complex model is the Dehn Particle Dynamics of Penetration (PDP) Model[2] which will predict, not only the residual speed of the fragment and the exit angle formed by the fragment's path, but also the residual speed and exit angle for the ricochet condition and the range of striking speeds over which the fragment will embed in the target plate (striking speeds just below the ballistic limit). As with the development of any model of a complicated physical process, basic experimental data is required.

A review of the literature revealed that very little data exist for the purpose of implementing the PDP Model, especially when the angle of incidence is not zero degrees and when the fragment ricochets. Thus it was necessary to conduct an experimental program at BRL to generate the required data. Although spheres are not typical of the shape of average spall fragments, the penetration and ricochet effects of fragments impacting on solid targets is so poorly understood that, for modelling purposes, simple geometric shaped fragments are required. Since the simplest geometry possible is the sphere, the sphere was chosen as the penetrator for this program. The spheres used were unmodified steel ball bearings which are readily obtainable in various sizes. The two sizes chosen for this program were 1/4 inch (0.635 cm) and 15/32 inch (1.191 cm) diameters. When the model is shown to accurately predict exit speeds and angles for spheres, then an attempt can be made to expand the model to handle other geometric shapes. Aluminum was chosen as the target material since components found in U.S. and Soviet vehicles are often encased in aluminum. The type of aluminum used as target plates was the 2024 aluminum (See the tables of Appendix A for the identification and the Brinell hardness numbers.)

[1] *John Zook, "An Analytical Model of Kinetic Energy Projectile/Fragment Penetration," BRL-MR 2797, October 1977*

[2] *James Dehn, "The Particle Dynamics of Target Penetration," ARBRL-TR-02188, September 1979 (ADA 077114)*

II. DESCRIPTION OF PARAMETER AND MEASUREMENT TECHNIQUES

In this study, there are three specific categories of data with respect to the fragment target interaction. At relatively low striking speeds and/or large impact angles (obliquities), the fragment will ricochet. At moderate speeds there can be a short range of striking speeds over which the fragment will embed in the target. At higher striking speeds, the fragment will completely penetrate the target plate, resulting in the fragment exiting the other side with some residual speed (complete penetration).

Figure 1 illustrates the definitions of the angles corresponding to a complete penetration and a ricochet. The impact angle θ is the angle between the fragment incident path and a perpendicular (normal) line drawn through the target at the point where the fragment incident path intersects the front surface of the target (impact point). Therefore, a fragment incident path which forms a zero degree impact angle will coincide with the normal to the target. The exit angle α for complete penetration is the angle between the line perpendicular to the rear of the target (passing through the point of exit) and the fragment exit path. These two definitions imply that the normal to the entrance side and the normal to the exit side do not necessarily pass through the same point on the target surface, which is predominately true for oblique impacts. The definition of the ricochet angle γ is similar to the definition of the exit angle except that the angle is measured to the ricochet path and will always be greater than 90 degrees. The exit angle is defined to be positive if counterclockwise from the perpendicular and negative otherwise.

The motion of the fragment (sphere or penetrator) is recorded by the flash x-ray arrangement depicted in Figure 2. Initially, the fragment is propelled toward the target along the shot line by being fired from a .50 caliber smooth bore gun (which requires using a sabot). The fragment perforates the first trigger screen (T_1) which initiates several events involving x-ray tubes 1, 2, and 3. These events result in the recording of images of the fragment on x-ray film as a function of time such that information related to the fragment striking speed can be determined. The fragment then perforates the second trigger screen (T_2) which initiates several events as a function of time involving x-ray tubes 4, 5, 6, and 7. The result of these events is the recording of images on x-ray film from which the fragment exit speed and fragment exit angle can be determined. For most of the shots an attempt was made to recover the fragment in sheets of celotex which were centered on the expected exit line. The angle of obliquity was changed by rotating the target plate.

A schematic of the sequence of events mentioned above is presented in Figure 3. The first time sequence begins when the fragment perforates the first screen (T_1). This triggers a time delay unit and, optionally, a time counter. At the end of the time delay, a pulse is emitted by the time delay unit which stops the first optional time counter, starts another time counter and a second delay unit. It also causes tubes 1 and 3 to flash. At the end of the second time delay, the second time delay unit releases a pulse which stops the second time counter and causes tube 2 to flash. A similar sequence begins when the fragment perforates a second trigger screen. The time delay interval for the third delay unit is set manually before the shot and is determined by

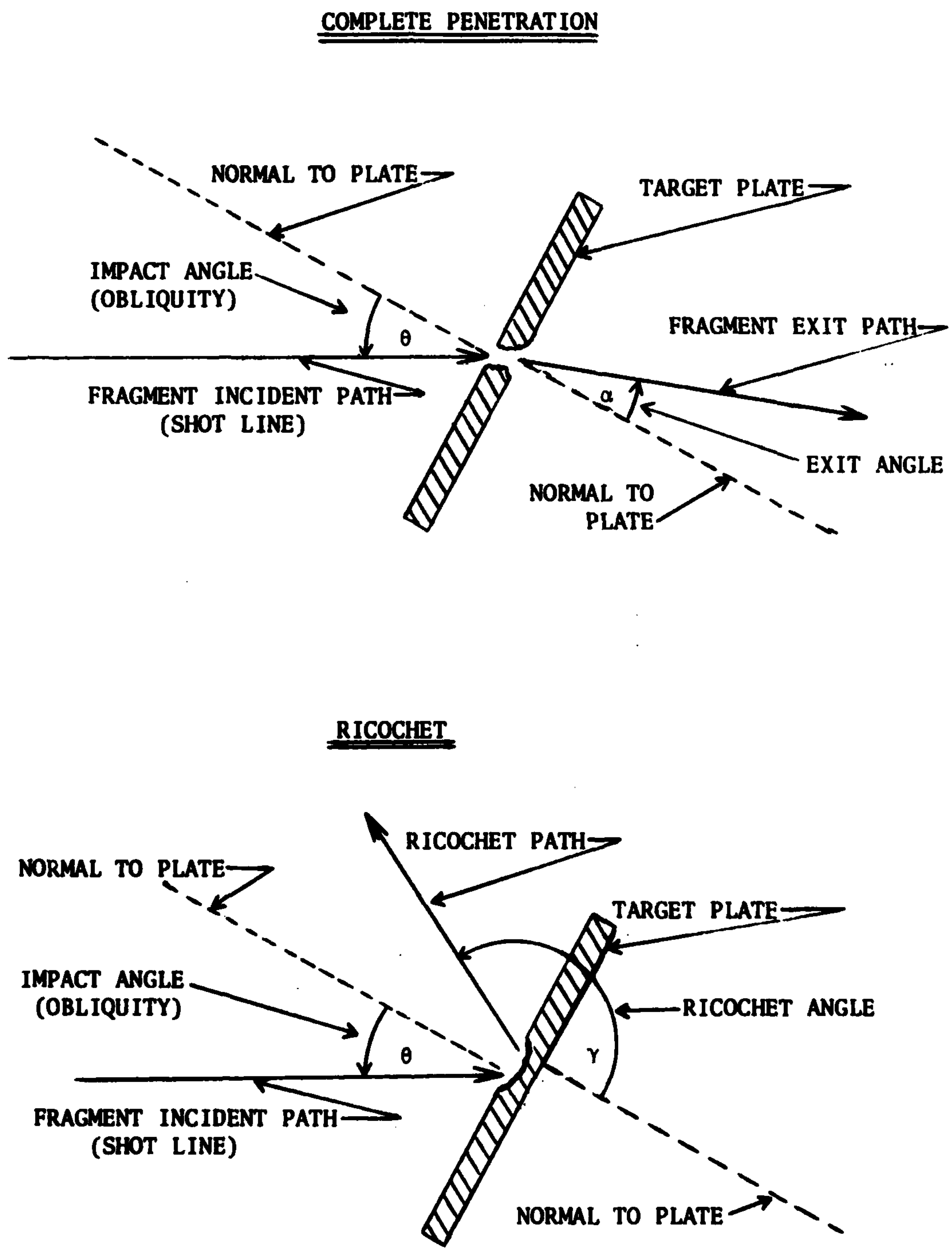


FIGURE 1 THE ANGULAR GEOMETRY FOR A FRAGMENT IMPACTING A TARGET.

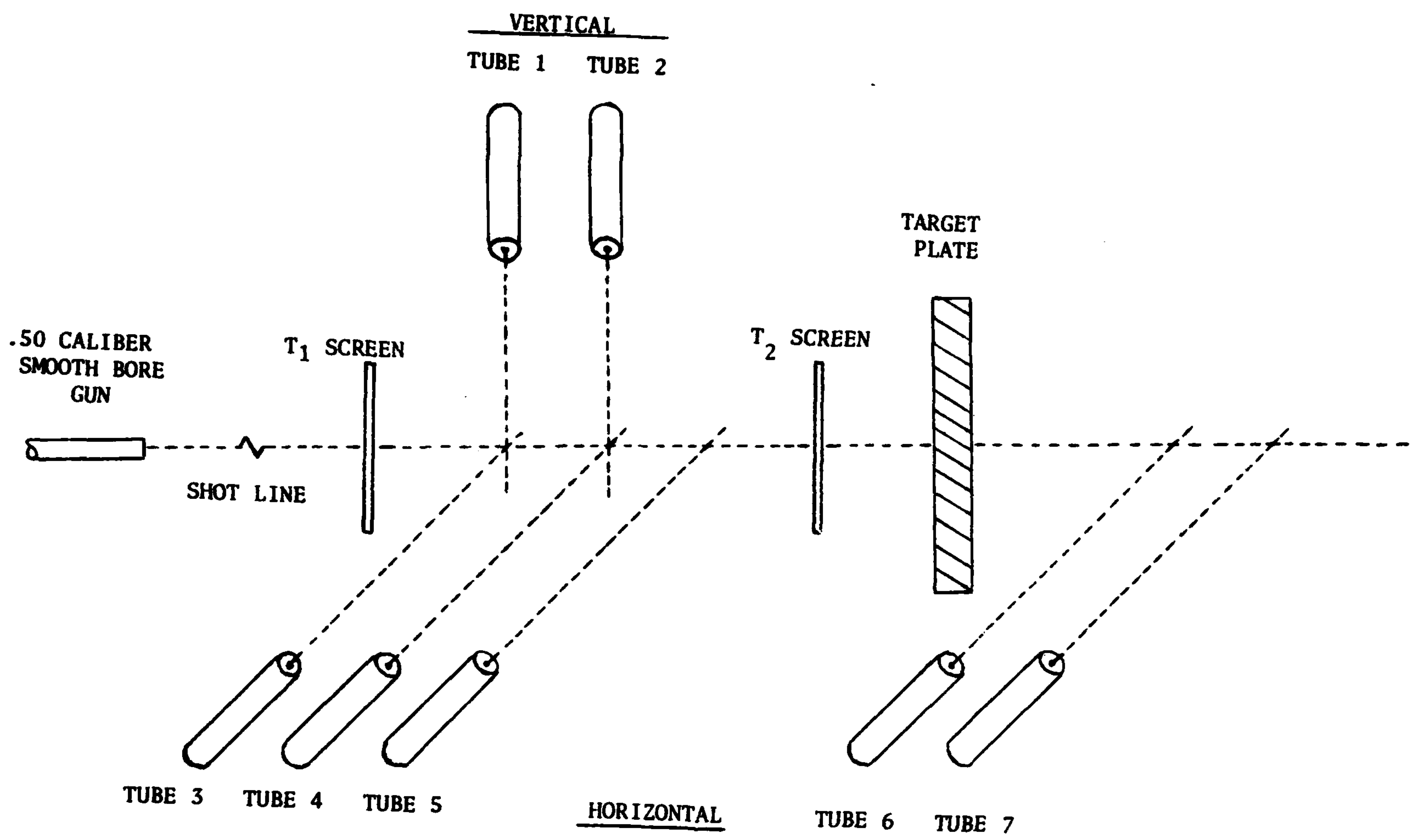


FIGURE 2 The Flash X-ray Arrangement For Measuring Fragment Velocity Data

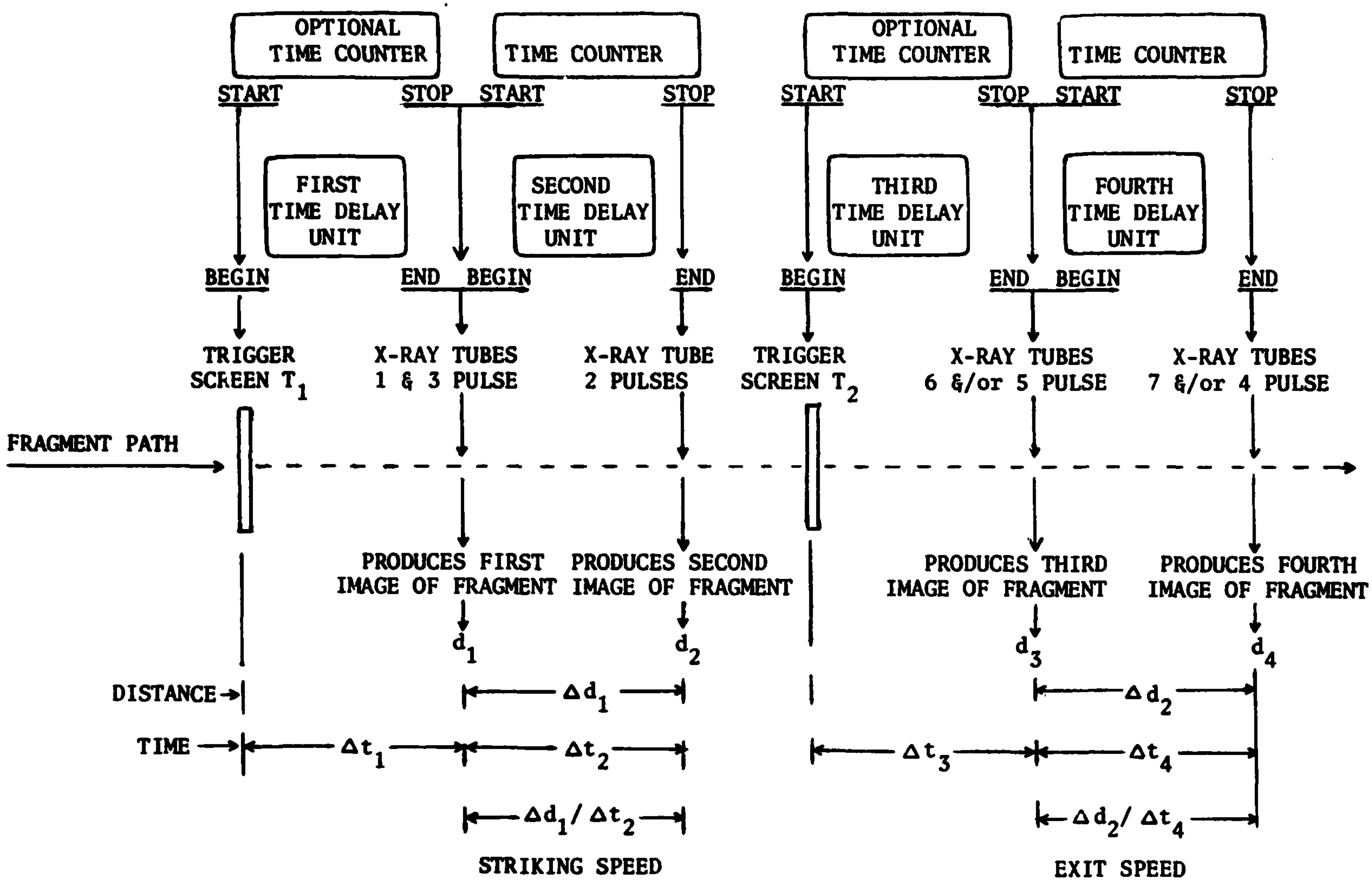


FIGURE 3 Sequence Of Events For Measuring Fragment Velocity Data

summing the time to travel from the trigger screen to the target based on the expected striking speed plus 10 to 200 microseconds within the target (depending on the striking speed and target obliquity), plus sufficient time to get the fragment into the field of view based on the expected exit speed. When ricochet is anticipated, the system is adjusted so that tube 5 and then tube 4 is pulsed. When perforation is anticipated, the system is adjusted so that tube 6 and then tube 7 is pulsed. When it is uncertain whether the event will be a perforation or a ricochet, then tubes 5 and 6 are set up to pulse simultaneously and tubes 4 and 7 are set up to pulse simultaneously.*

The images of the fragment are formed by the pulsed x-ray heads on photographic film sheets placed in planes perpendicular to the respective x-ray tubes and eight inches (20.32 cm) from the plane of the respective orthagonal x-ray heads. Images of fiducial wires located directly in front of the film plane are also formed. By measuring the coordinate values of the center of mass of the image formed on the film with respect to the fiducial wire images, corrections can be made to determine the actual coordinates of the fragment corresponding to the time the x-ray tubes are pulsed. The speed of the fragment is calculated by dividing the difference between the actual fragment positions (Δd) by the corresponding difference of the time (Δt) recorded by the time counter. The angle at which the fragment is traveling can also be determined.

Backup calculations of the speeds were made by using an electronic digitizer controlled by a desktop computer. Any discrepancies between the manually computed speed and the digitized computed speed greater than ten meters/second were resolved. Usually the difference between the two methods did not exceed two meters/second.

The accuracy of the striking speed and exit angle are greatly dependent on the degree of image separation appearing in the x-ray films. The further apart the images are, the greater the accuracy since the percentage error in determining the coordinate values is less and, in general, the time base is longer. The firing range imposes limitations on the image separation which depend on the size of the film, the head to film distance, the shot line to film distance, the x-ray head separation and on how well the preset time delays are selected. The latter depends to a great extent on previous experience and how well the result of the event can be anticipated. Assuming good image separation and accurate time counters, the error in the speed is within 0.3% and the error in the angle is within 0.5 degrees.

The effects of the fragment impact on the target plate were recorded by taking measurements of certain parameters. Figures 4a and 4b illustrate these parameters for the complete penetration condition. In this report, the

This was the initial sequence, but was modified after a number of shots had been conducted. The modification consisted of dropping tube 4, pulsing tubes 6 and 7 in sequence for complete penetration, tubes 6 and 5 in sequence for ricochet or tube 6 and then tubes 5 and 7 simultaneously.

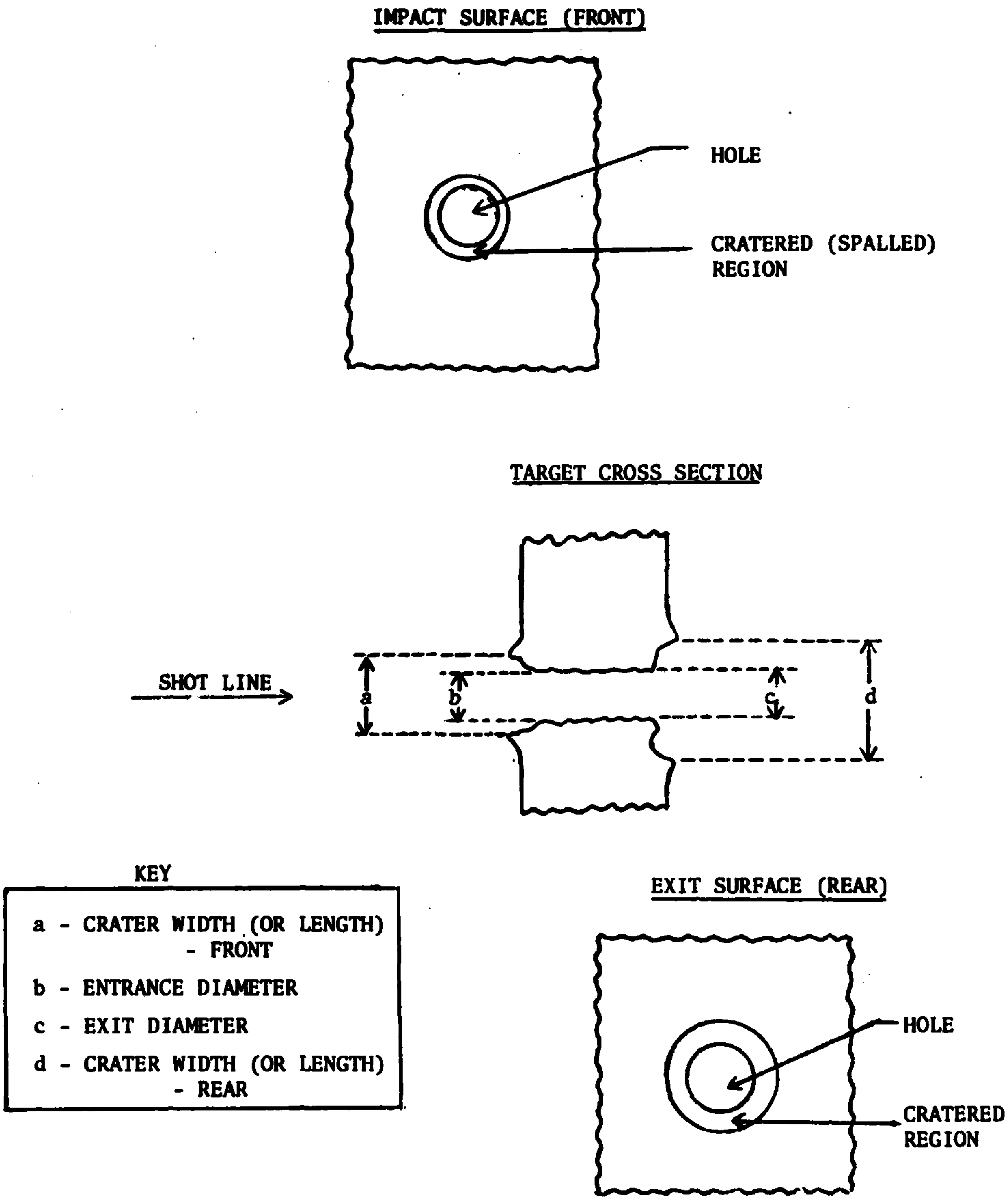


FIGURE 4a Target Surfaces And Cross Section Defining Measured Target Parameters For Normal Impact Under Complete Penetration Conditions

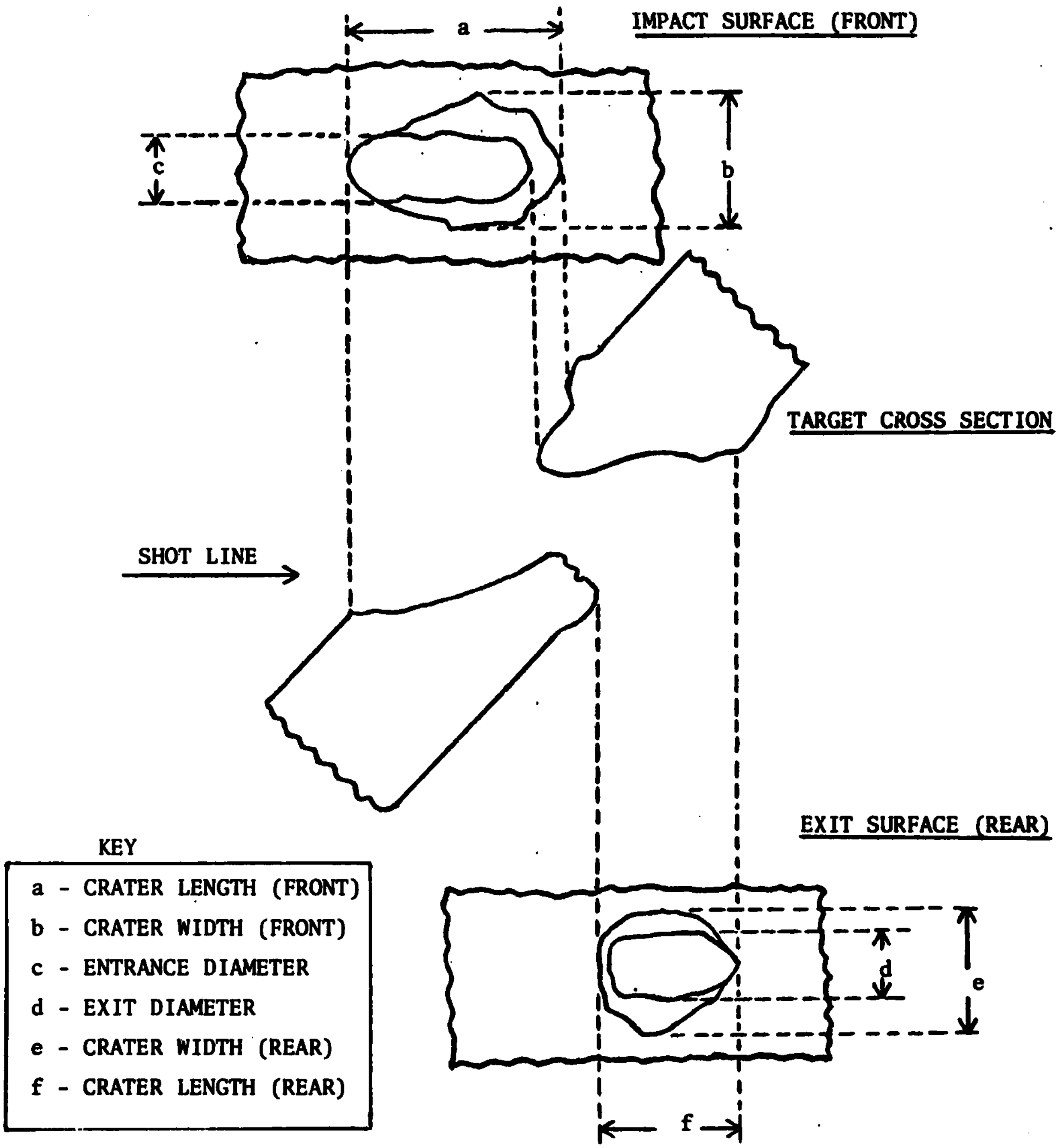


FIGURE 4b Target Surfaces And Cross Section Defining Measured Target Parameters For Oblique Impact Under Complete Penetration Conditions

definition for complete penetration is more restrictive than that of target perforation. That is, a perforation is defined as the creation of a hole in the target such that light can pass through. A complete penetration occurs when the exit hole is large enough to allow the penetrator to exit from the rear surface of the target. The sphere can ricochet but have perforated the target. Figures 5a and 5b illustrate the target effects parameters for the ricochet condition. The following are verbal definitions of the measured target effects parameters.

Hole Diameters:

Entrance (normal impact): The diameter of the hole made by the sphere on the entrance side of the target (does not include the crater).

Entrance (oblique impact): Maximum width of the impression made by the sphere at initial contact and is usually the inside edge of the cratered (spalled) region. (The spall region exists whenever target fragments break away from the target due to the shock wave causing the target plate to fracture.)

Exit (normal impact): The diameter of the hole made by the sphere on the exit side of the target, not including the cratered region.

Exit (oblique impact): Maximum width of the hole made by the sphere at the point where the sphere lost contact with the target plate.

Crater Dimensions:

Width (normal impact): Minimum diameter of the cratered (spalled) region.

Width (oblique impact): Length of minor axis of the elliptically shaped cratered region.

Length (normal impact): The maximum diameter of the cratered region.

Length (oblique impact): The length of the major axis of the elliptically shaped cratered region.

Groove Dimensions (Oblique impacts only):

Width: The maximum width of the impression made by the passage of the sphere.

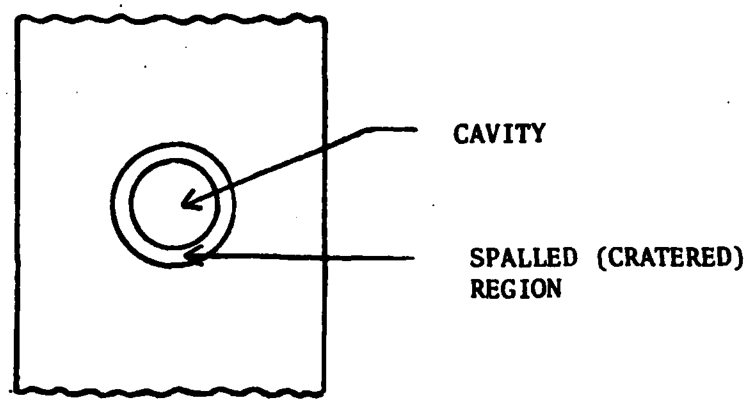
Length: The maximum length of the impression made by the passage of the sphere.

Depth of Penetration:

Perpendicular Depth of Penetration: The maximum penetration measured from the plane of the original target surface.

LOS Depth of Penetration: The line-of-sight distance from the impact point to the point where the maximum perpendicular depth occurs.

IMPACT SURFACE (FRONT)



KEY

a - CRATER WIDTH (OR LENGTH) - FRONT

b - ENTRANCE DIAMETER

c - Line-of sight (LOS) DEPTH OF PENETRATION (also PERPENDICULAR DEPTH)

TARGET CROSS SECTION

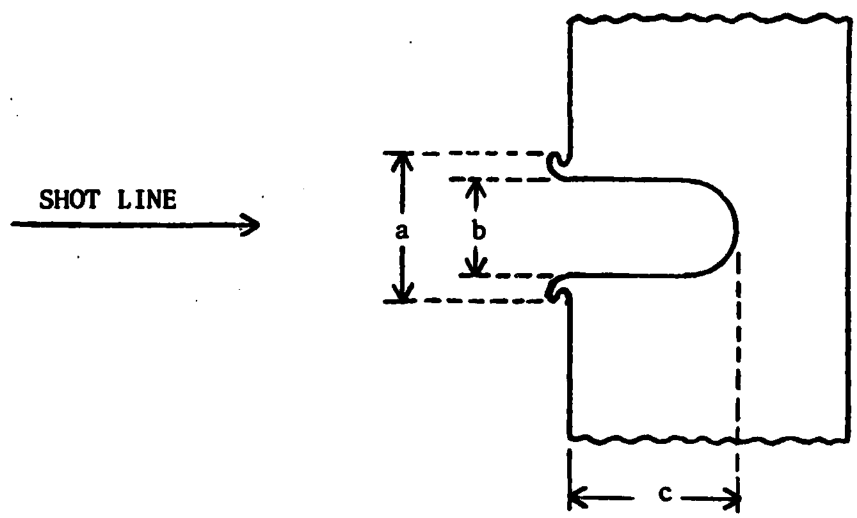


FIGURE 5a Target Surface And Cross Section Defining Measured Target Parameters For Normal Impact Under Ricochet Or Embedment Conditions

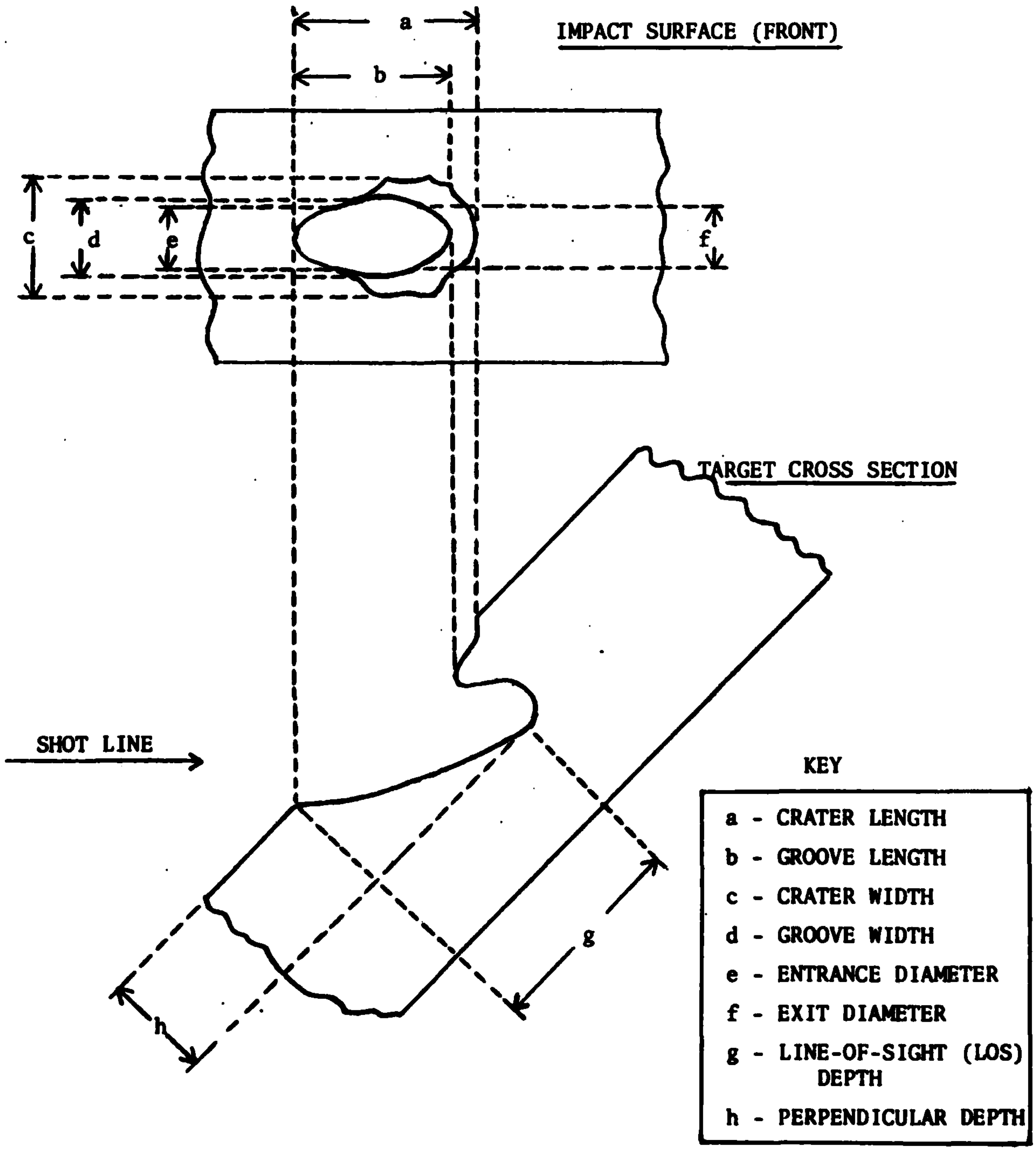


FIGURE 5b Target Surface And Cross Section Defining Measured Target Parameters For Oblique Impacts Under Ricochet Or Embedment Conditions

Rear Surface Bulge: The "height" of the bulge, i.e., the distance from the original rear target surface to the peak of the bulge.

The measurement of these target effects parameters (Tabulated values are in Appendix A.) also entail a certain amount of error due to the measuring technique. The hole diameters, crater dimensions and line-of-sight (LOS) depth (oblique impacts) were measured using a vernier caliper. The perpendicular depth of penetration and the rear surface bulge height were measured using a "home made" depth (or height) feeler gauge consisting of a center screw surrounded at equal angles and distance by three short screws set in a 1/4 inch x 2 inch x 5/8 inch (0.635 cm x 5.705 cm x 7.938 cm) aluminum plate. (Later, a larger one was utilized.) The center screw was adjusted with the other screws resting on the plane of the original target surface and a measurement then made on the center screw using a vernier caliper. At normal impact angles, the error for these measurements is within 0.1 cm except for the depth of penetration when the sphere embedded in the target. When embedment occurred, an estimate of the depth was determined by adding the diameter of the ball to the measured value of the distance between the impact surface and the "top" of the sphere. This method does not take into account possible sphere deformation or any bounce back from the maximum penetration depth. At oblique angle impacts, the tabulated hole diameters are not well defined; that is, the point at which the measurement is made requires subjective judgement. Therefore, the error on these values is estimated to be within 0.3 cm. The crater measurements involve the maximum dimensions of the cratered region and are within 0.1 cm. The groove width and length also require a certain amount of subjective judgement and the error is estimated to be within 0.2 cm.

The plate thicknesses indicated in the tables of Appendix A are nominal values. Measurements, made by using a micrometer, varied as much as 0.01 cm over a particular plate and as much as 0.02 cm from plate to plate. Brinell hardness numbers (BHN) were determined by using a commercially available Brinell hardness tester. Measurements on thick plates involved the standard 10 mm diameter ball at a 3000 Kg load. The 10 mm diameter ball at 500 Kg load was used for the 1/4 inch (0.635 cm) plate. In every case the measured Brinell value is higher than the handbook value of 120 for 2024-T3 type aluminum. The BHN values reported in Appendix A are also nominal values.

Also tabulated in Appendix A are the masses and diameters of all recovered penetrator fragments. In the case where the sphere broke up, the masses of the recovered pieces are reported as the final table in the Appendix. The masses were measured using a standard laboratory balance and are accurate to within 0.001 gram. The diameters were measured using a micrometer and are accurate to within 0.001 cm.

III. DATA ANALYSIS

III.1 DATA TRENDS

The most frequently used data in terminal ballistic studies are the exit speed, exit angle, and depth of penetration as functions of striking speed.

The values of these parameters are plotted in the figures in Appendix B with a single curve per figure. These plots are scaled so that the reader can easily compare various curves in any combination for some preferred comparison. The symbols appearing on the plots are centered at their respective values and are defined as follows:

R = ricochet	C = complete penetration
E = embedment	B = sphere breakup

The same data are also plotted in Figures 6 through 29 (using the same symbols) with more than one curve per plot so that the following analyses can be made.

EXIT SPEED VERSUS STRIKING SPEED

The exit speed as a function of striking speed for the 1/4 inch steel sphere impacting plates of three different plate thicknesses and three impact angles are presented in Figures 6, 7, and 8. In general, the effect of increasing the impact angle is to increase the values of the ricochet speed and the ricochet limit. (The ricochet limit is defined to be the largest striking speed at which the sphere ricochets.) In the complete penetration region, the various curves are generally parallel. In the case of Figure 8, the data show that the 1/4 inch sphere could not perforate the 2 inches of aluminum plate; thus, no complete penetration data were generated (i.e., the target acts as though it were of infinite thickness - called semi-infinite). In Figure 8, the 45 degree curve indicates that for oblique angle impacts, the ricochet limit can not be clearly specified since the data oscillate between a ricochet and an embedment.

Similar curves for the 15/32 inch steel sphere are presented in Figures 9, 10, and 11. The same observations are seen to be applicable as for the 1/4 inch steel sphere data. By comparing the curves presented in Figure 8 and Figure 11, it may be determined that when the targets are semi-infinite, the exit speed for a given striking speed is independent of the diameter of the impacting sphere.

EXIT ANGLE VERSUS STRIKING SPEED

Figures 12, 13, and 14 present the data for the exit angle as a function of striking speed at three different target plate thicknesses and the three different impact angles. Whenever the impact angle is 0 degrees, the ricochet angle is nearly 180 degrees and the complete penetration exit angle is nearly a constant 0 degrees. This is an expected result and the data would be suspect if otherwise. For oblique angle impacts, the exit angle exhibits rapid change for striking speeds near the ballistic limit. The exit angle for striking speeds well above the ballistic limit approaches asymptotically to an angle equal to the obliquity. Similar data for the 15/32 diameter sphere are presented in Figures 15, 16, and 17. The same comments are applicable to these data as mentioned above for the 1/4 inch diameter sphere. A comparison of the data for the semi-infinite targets in Figures 14 and 17, shows that the exit angle is nearly independent of the sphere diameter.

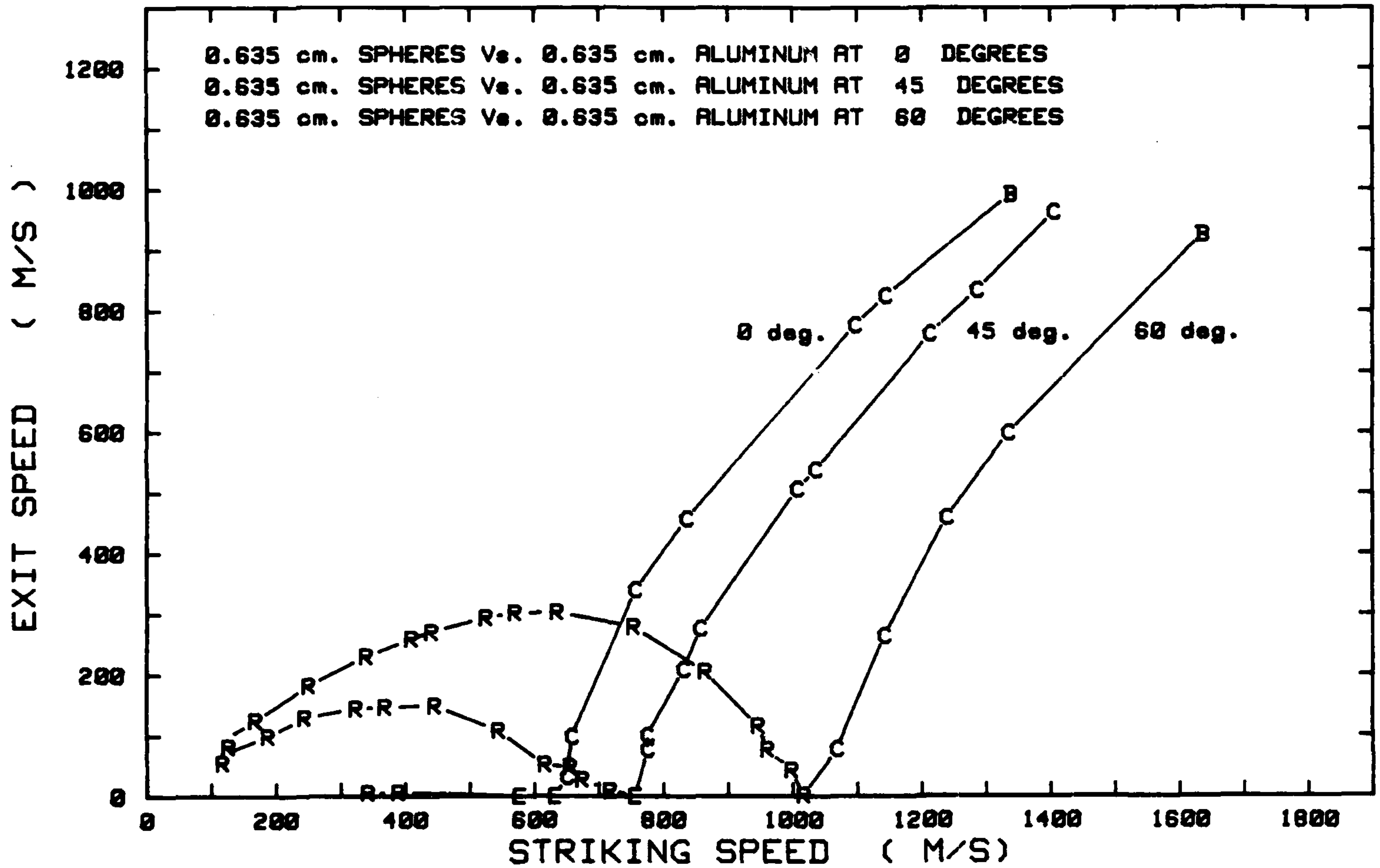


FIGURE 6 Exit Speed Versus Striking Speed For 1/4 Inch Steel Spheres Impacting 1/4 Inch Aluminum Targets At Three Impact Angles

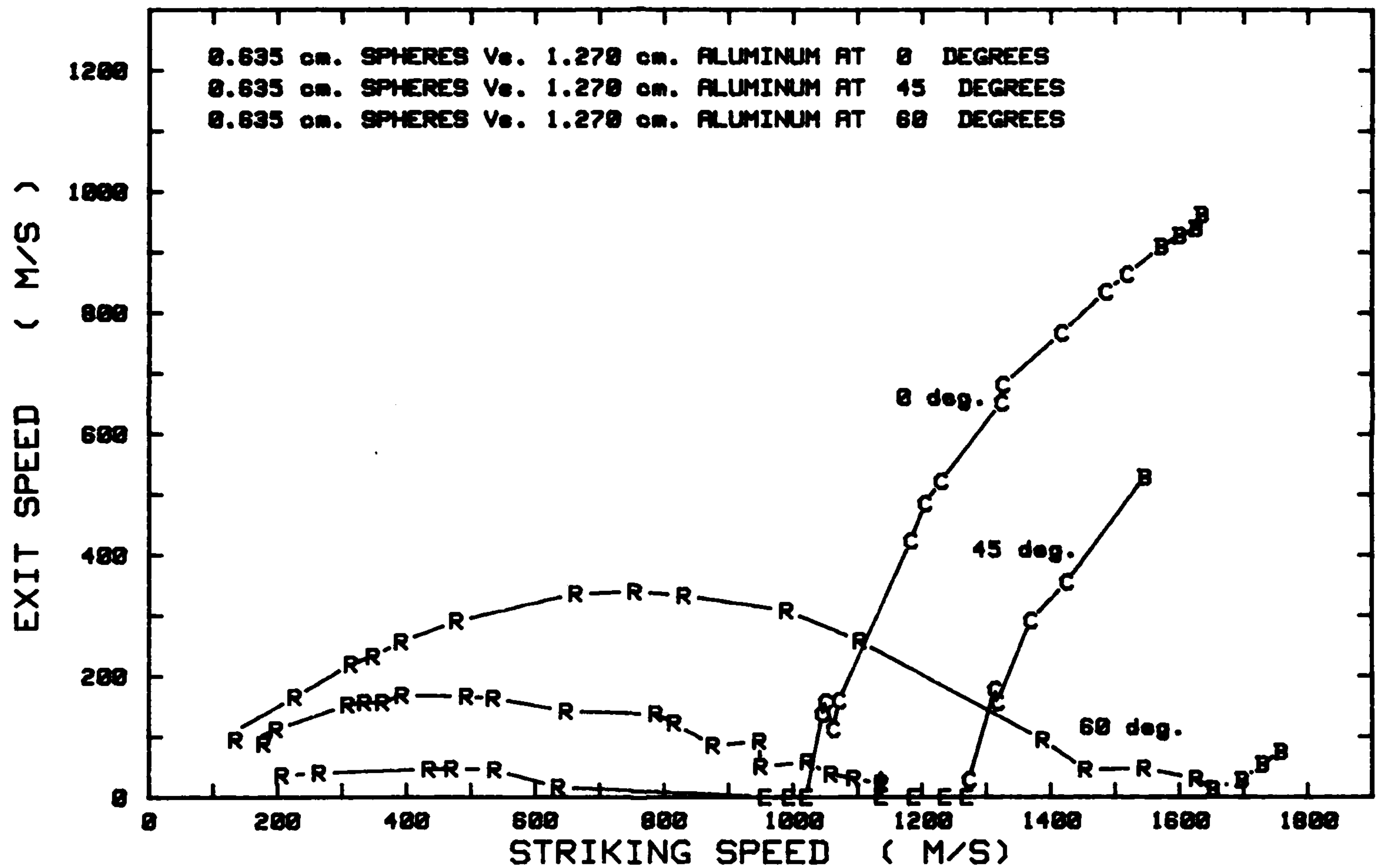


FIGURE 7 Exit Speed Versus Striking Speed For 1/4 Inch Steel Spheres Impacting 1/2 Inch Aluminum Targets At Three Impact Angles

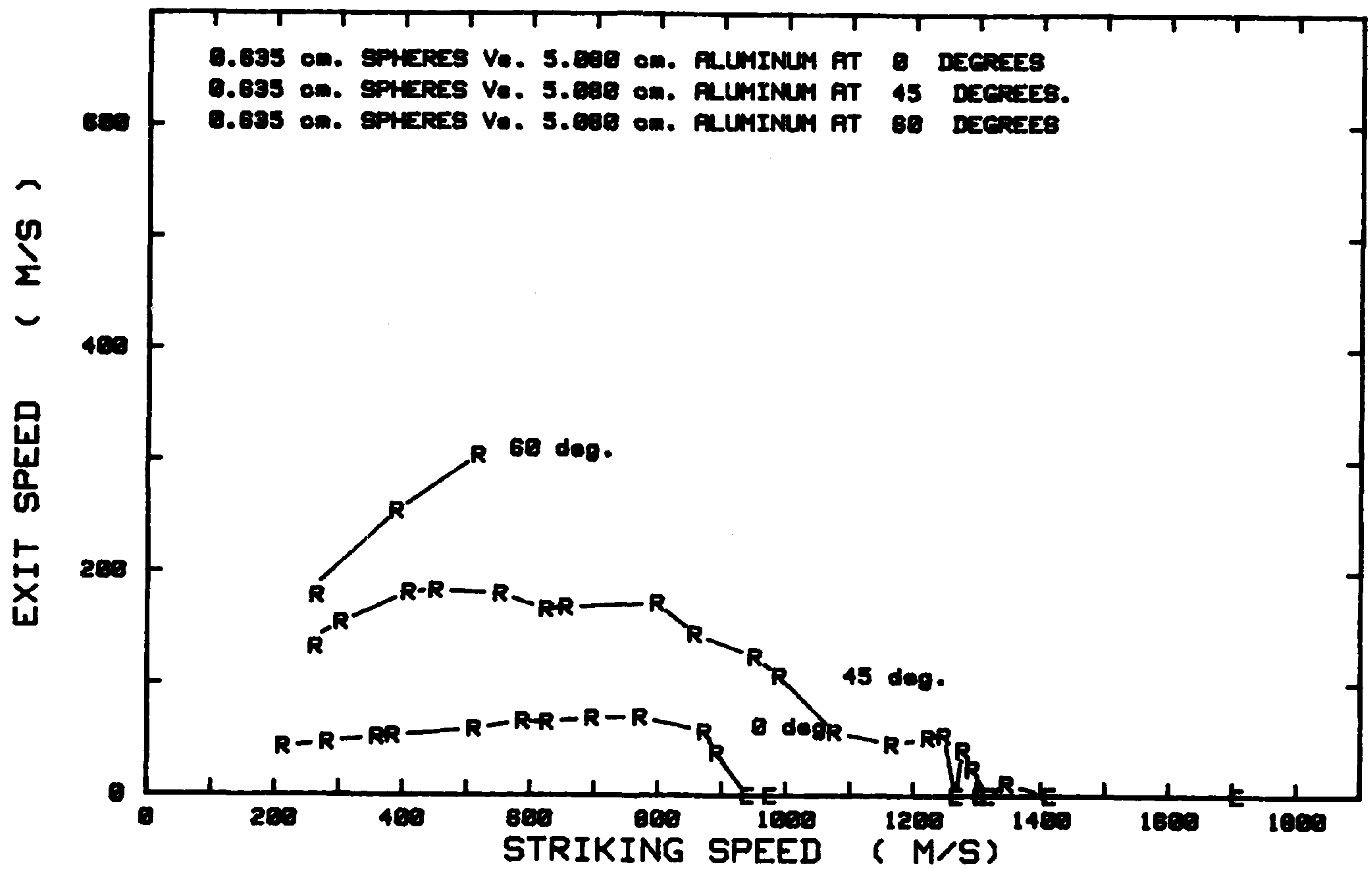


FIGURE 8 Exit Speed Versus Striking Speed For 1/4 Inch Steel Spheres Impacting 2 Inch Aluminum Targets At Three Impact Angles

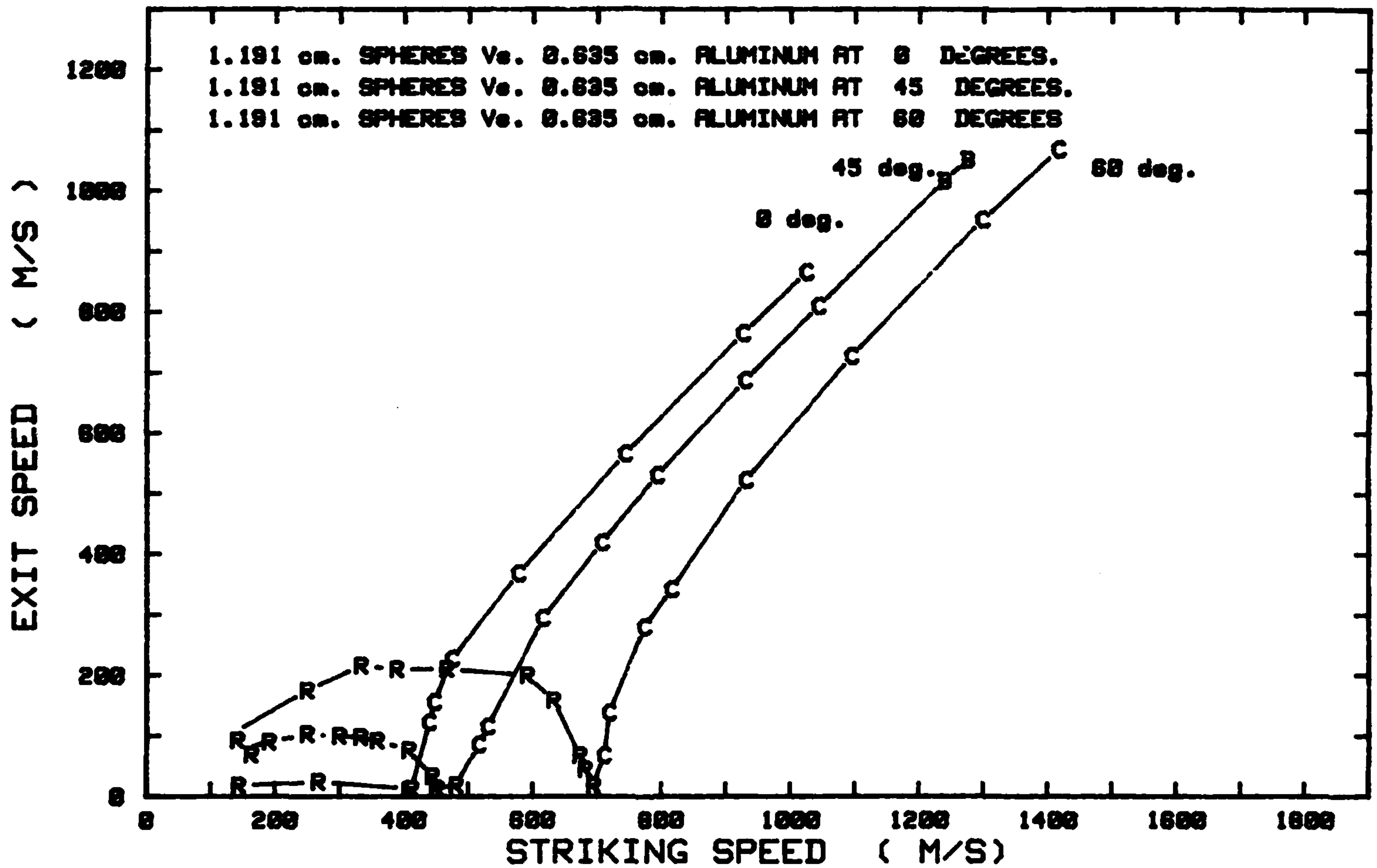


FIGURE 9 Exit Speed Versus Striking Speed For 15/32 Inch Steel Spheres Impacting 1\4 Inch Aluminum Targets At Three Impact Angles

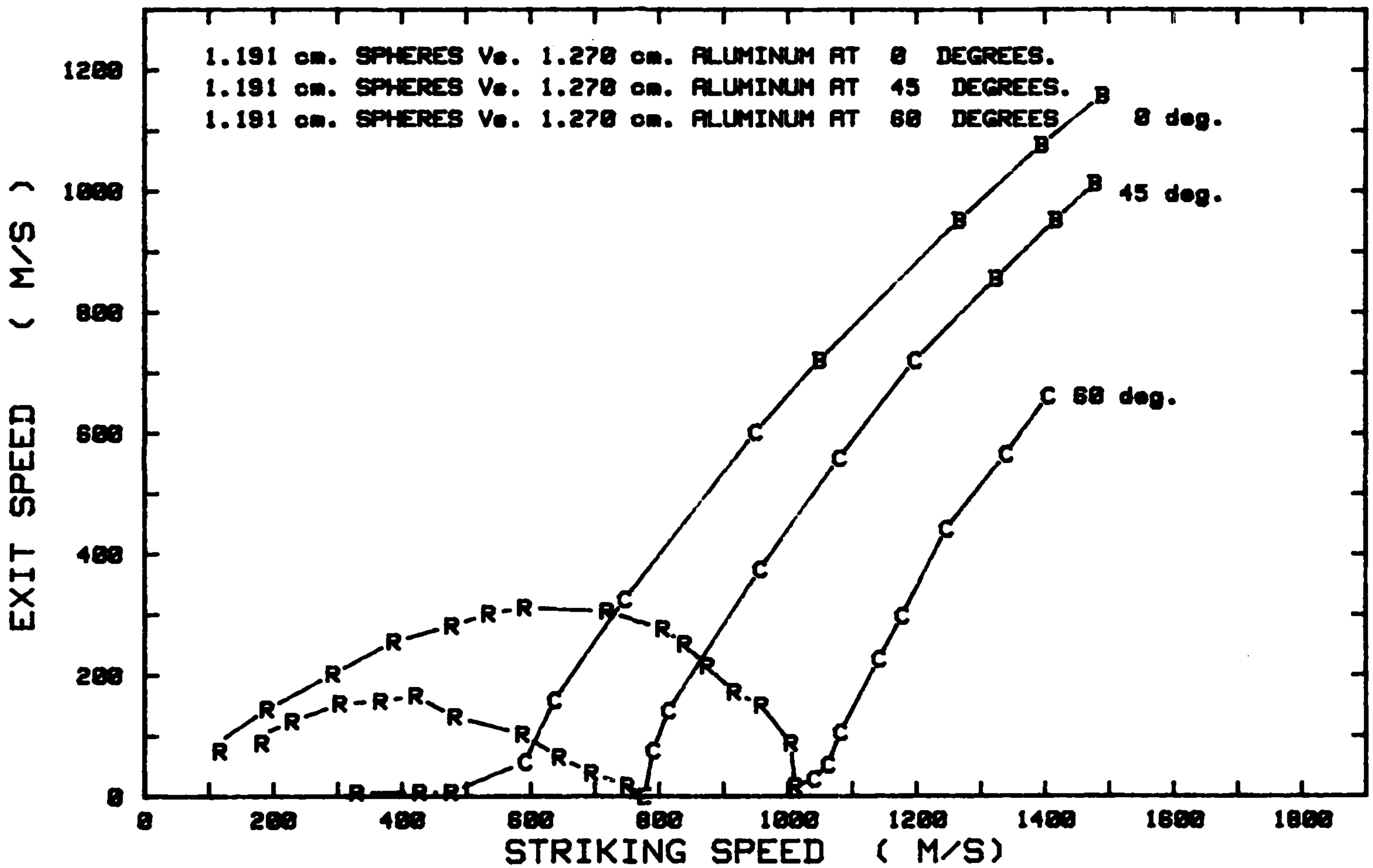


FIGURE 10 Exit Speed Versus Striking Speed For 15/32 Inch Steel Spheres Impacting 1\2 Inch Aluminum Targets At Three Impact Angles

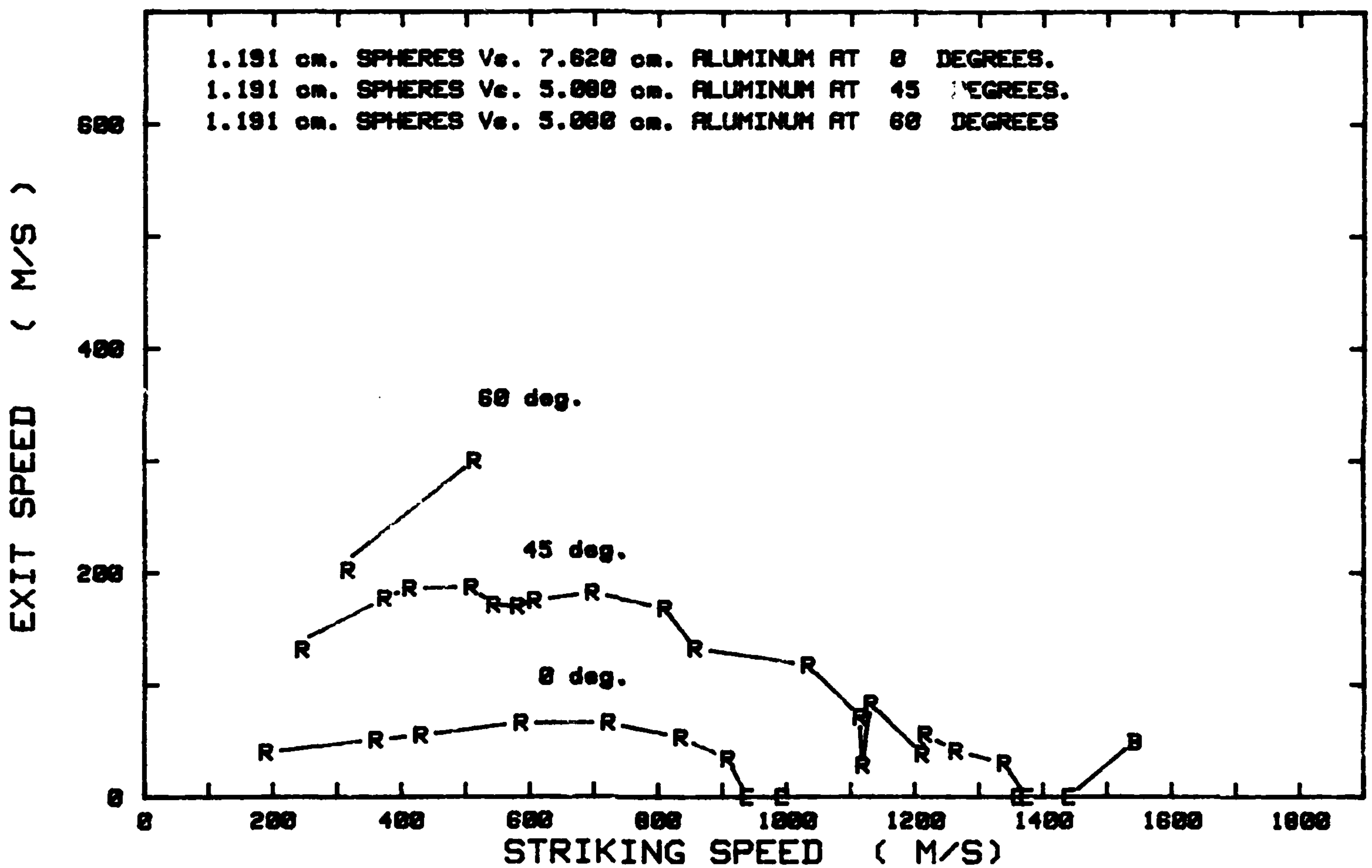


FIGURE 11 Exit Speed Versus Striking Speed For 15\32 Inch Steel Spheres Impacting 2 (or 3) Inch Aluminum Targets At Three Impact Angles

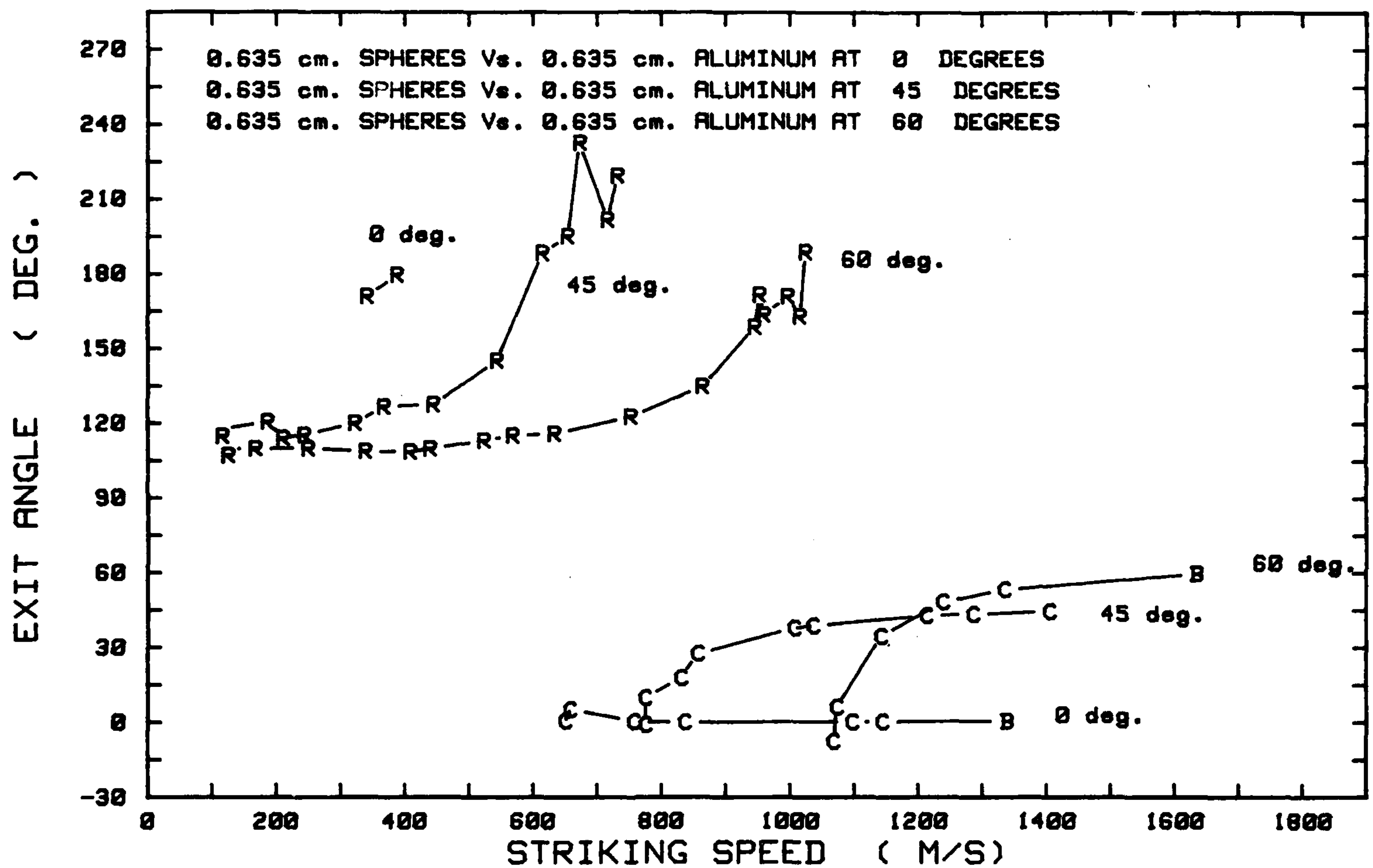


FIGURE 12 Exit Angle Versus Striking Speed For 1/4 Inch Steel Spheres Impacting 1/4 Inch Aluminum Targets At Three Impact Angles

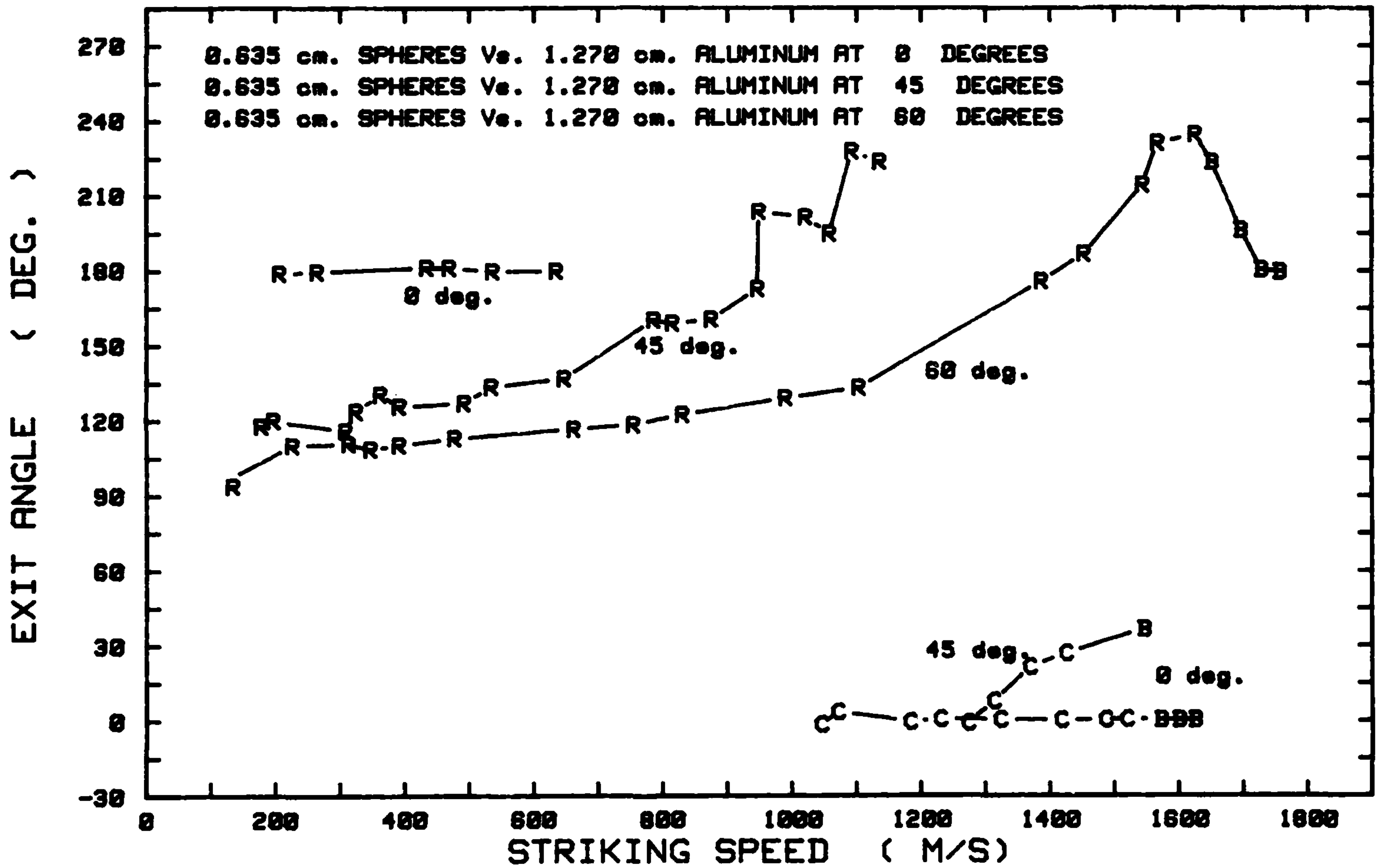


FIGURE 13 Exit Angle Versus Striking Speed For 1/4 Inch Steel Spheres Impacting 1/2 Inch Aluminum Targets At Three Impact Angles

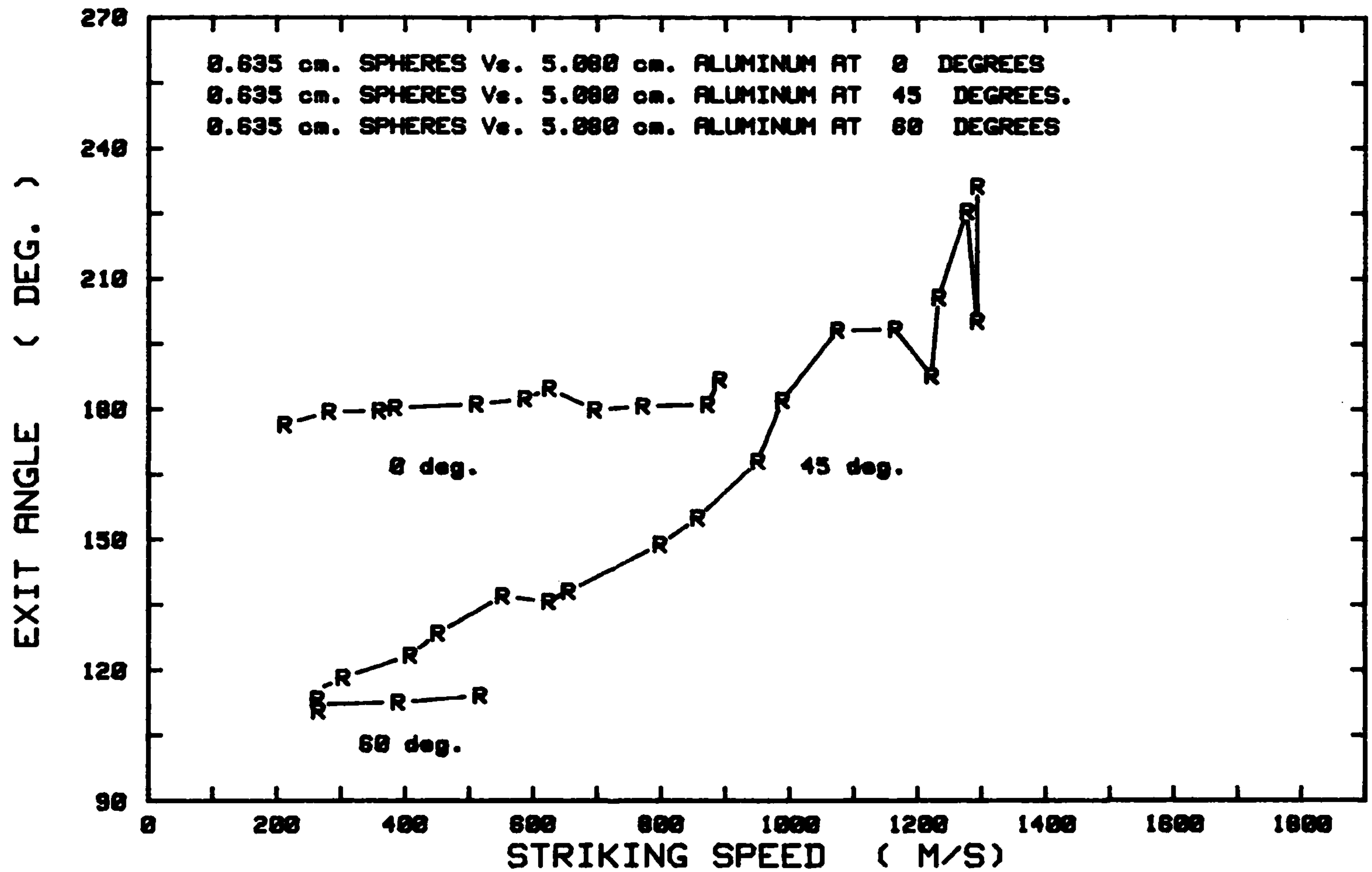


FIGURE 14 Exit Angle Versus Striking Speed For 1/4 Inch Steel Spheres Impacting 2 Inch Aluminum Targets At Three Impact Angles

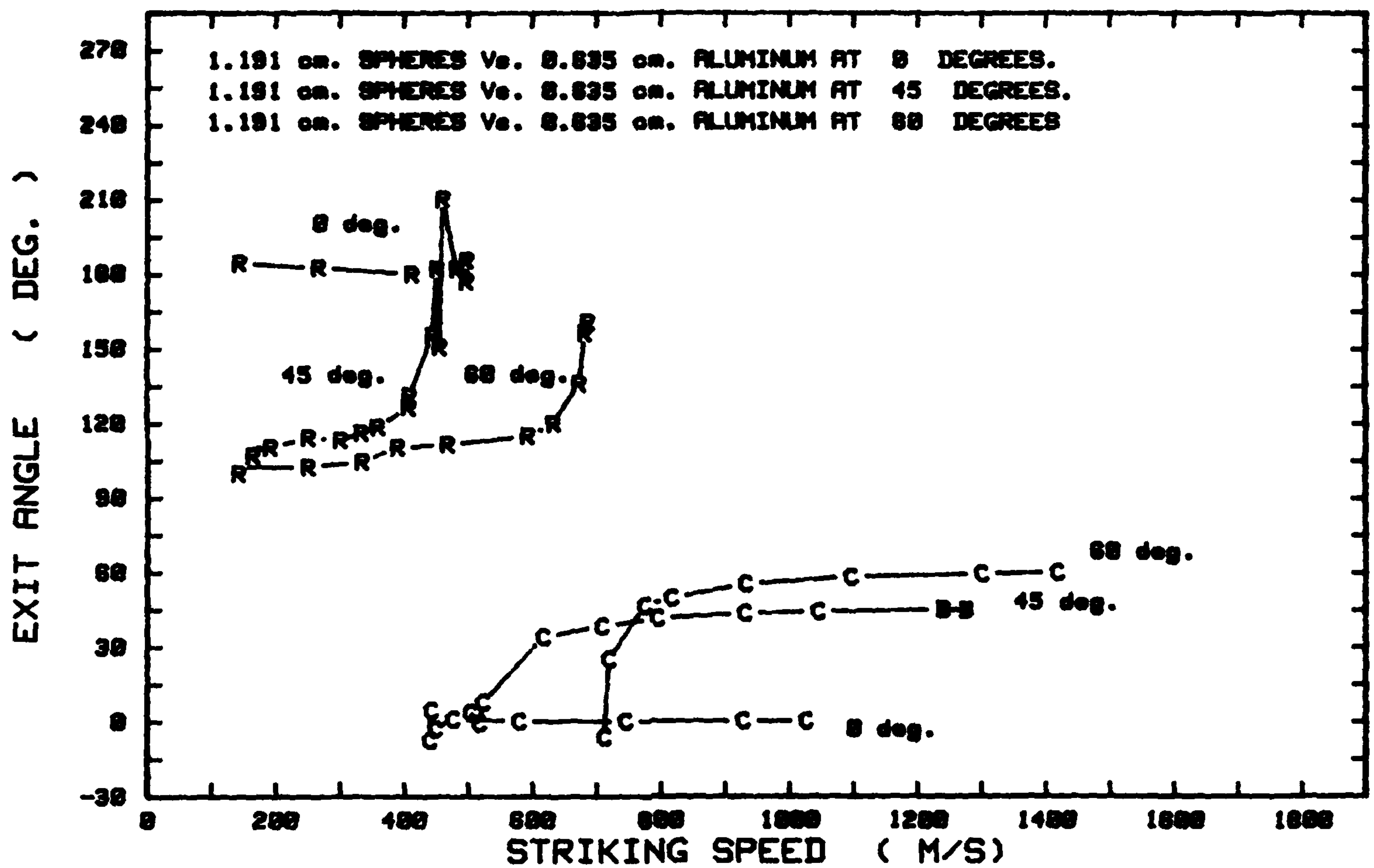


FIGURE 15 Exit Angle Versus Striking Speed For 15/32 Inch Steel Spheres Impacting 1\4 Inch Aluminum Targets At Three Impact Angles

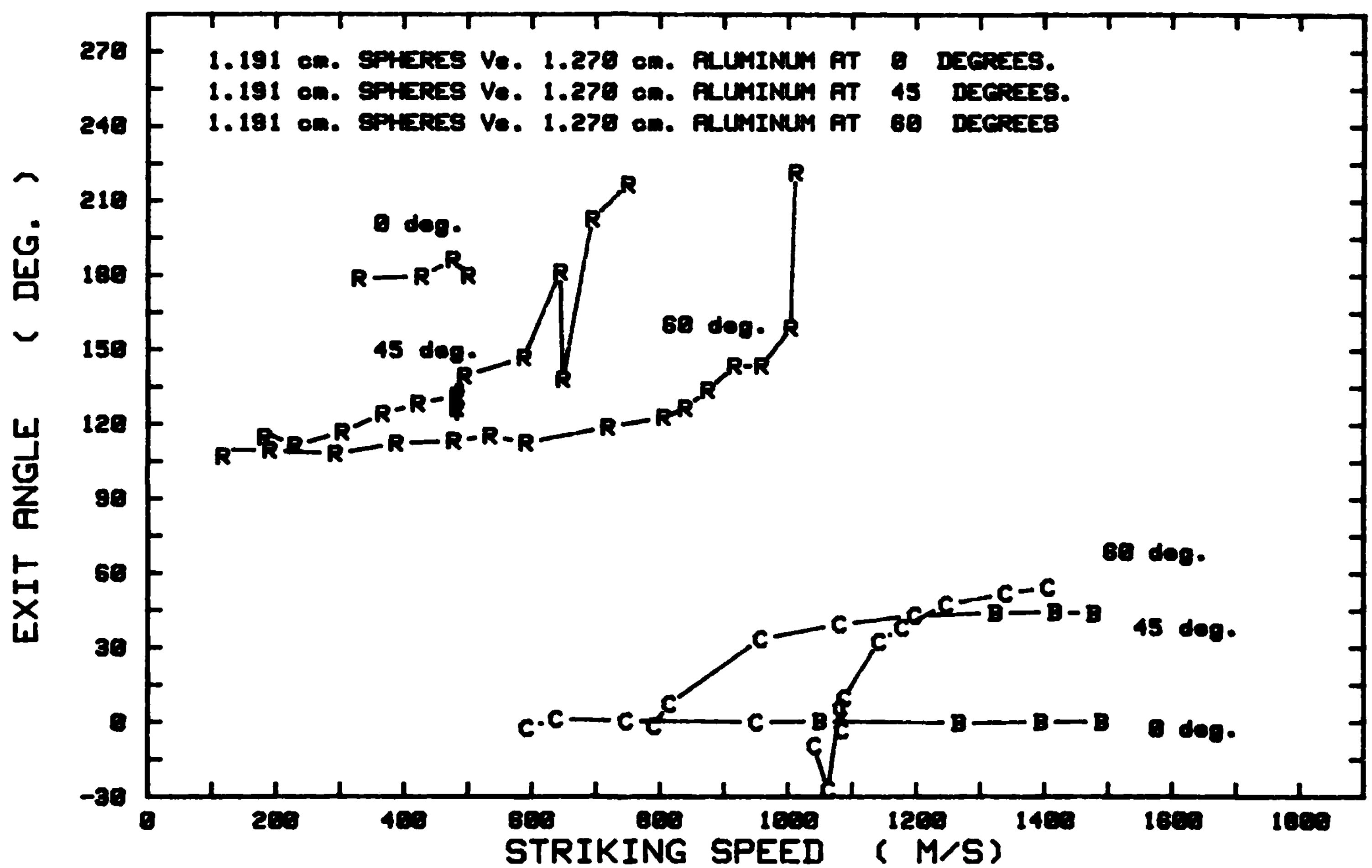


FIGURE 16 Exit Angle Versus Striking Speed For 15/32 Inch Steel Spheres Impacting 1\2 Inch Aluminum Targets At Three Impact Angles

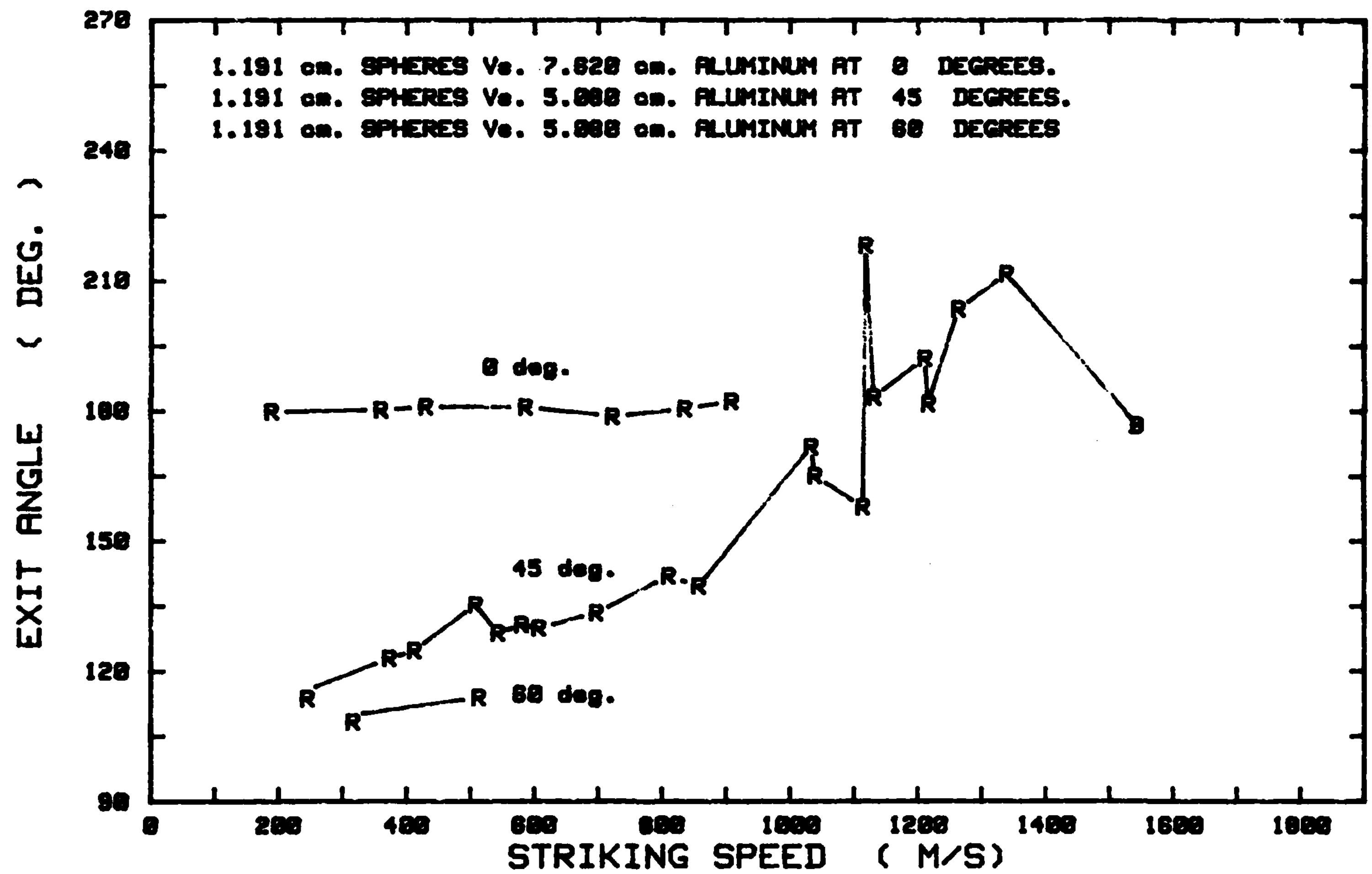


FIGURE 17 Exit Angle Versus Striking Speed For 15\32 Inch Steel Spheres Impacting 2 (or 3) Inch Aluminum Targets At Three Impact Angles

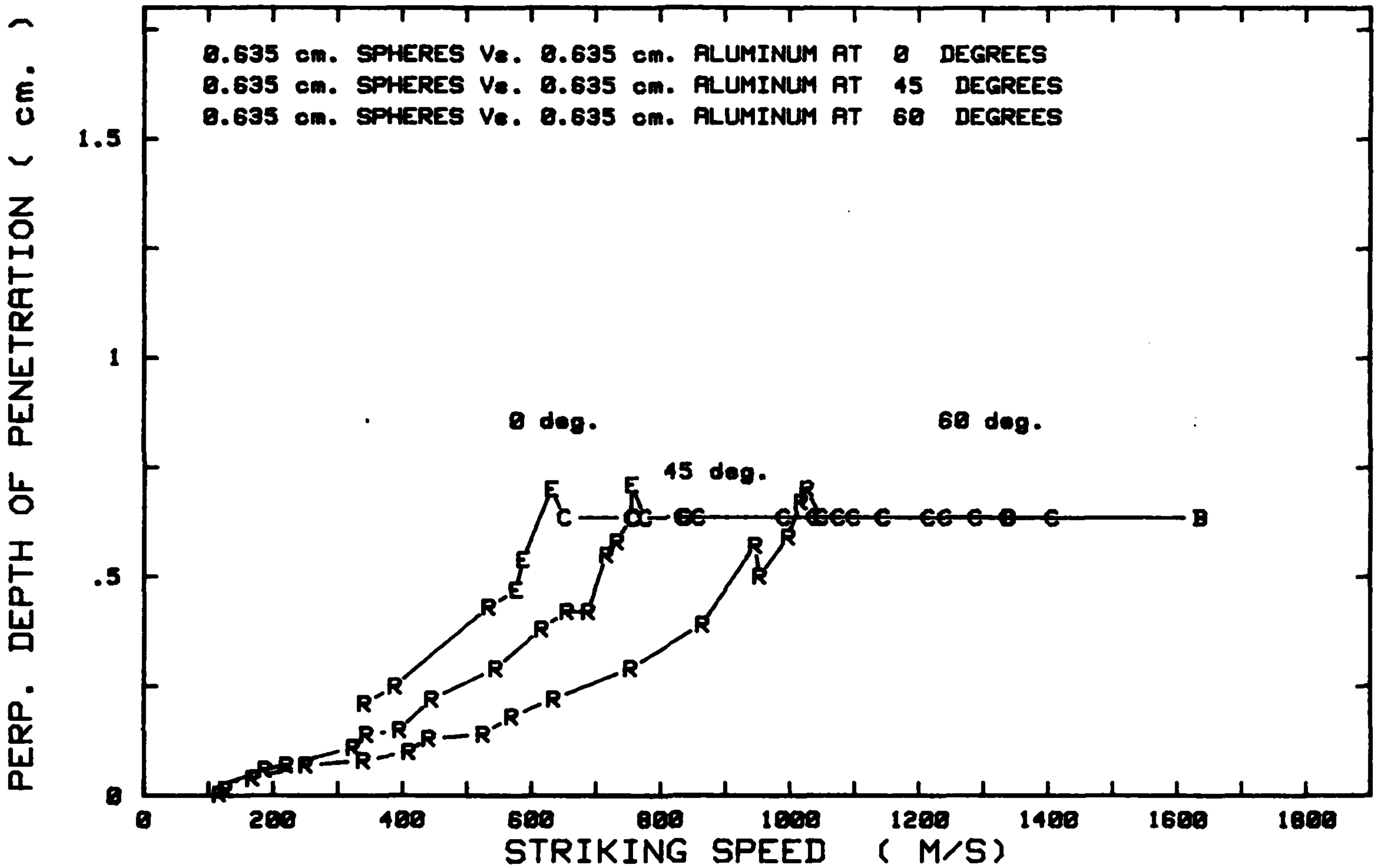


FIGURE 18 Perpendicular Depth Versus Striking Speed For 1/4 Inch Steel Spheres Impacting 1/4 Inch Aluminum Targets At Three Impact Angles

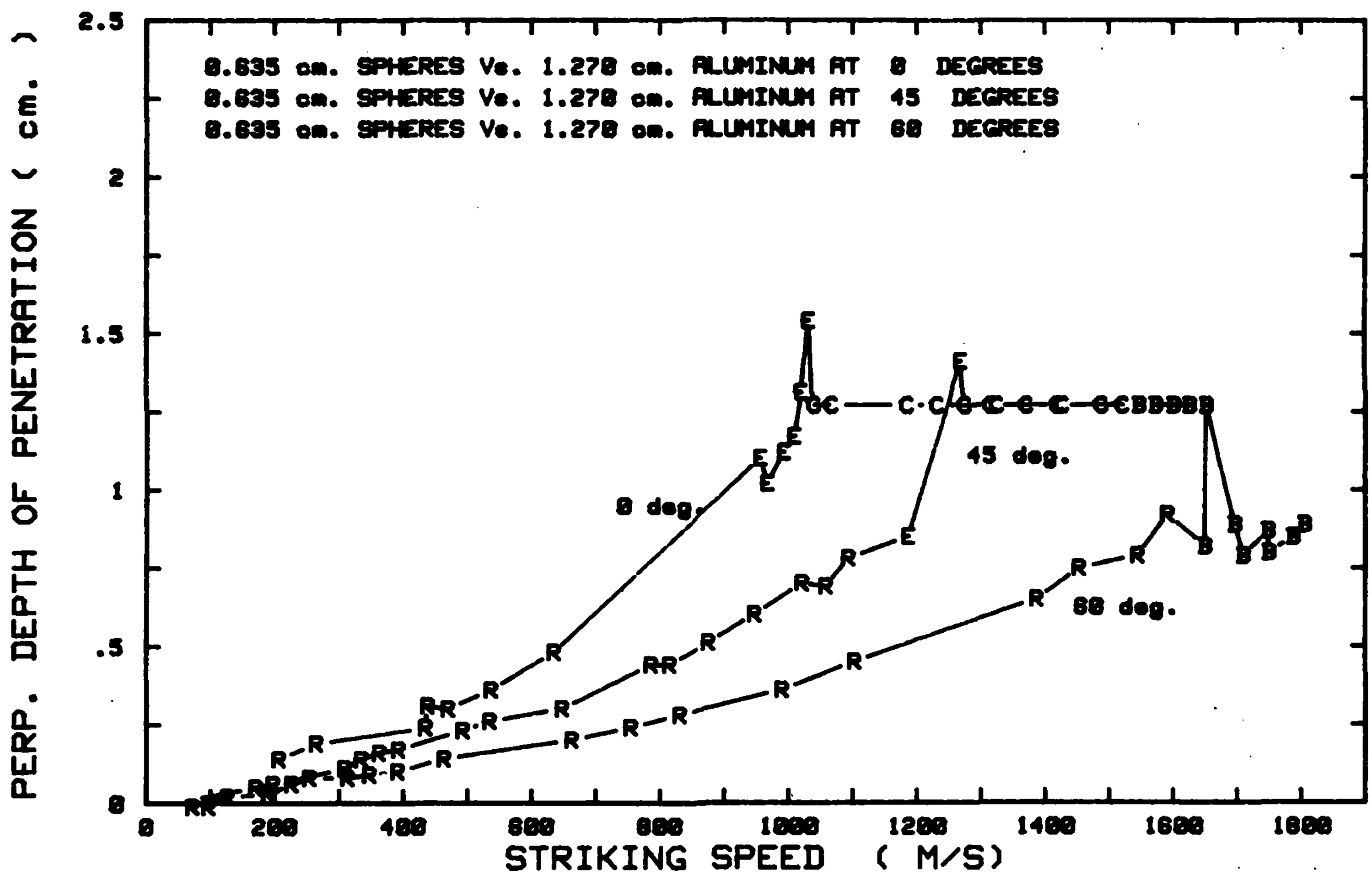


FIGURE 19 Perpendicular Depth Versus Striking Speed For 1/4 Inch Steel Spheres Impacting 1/2 Inch Aluminum Targets At Three Impact Angles

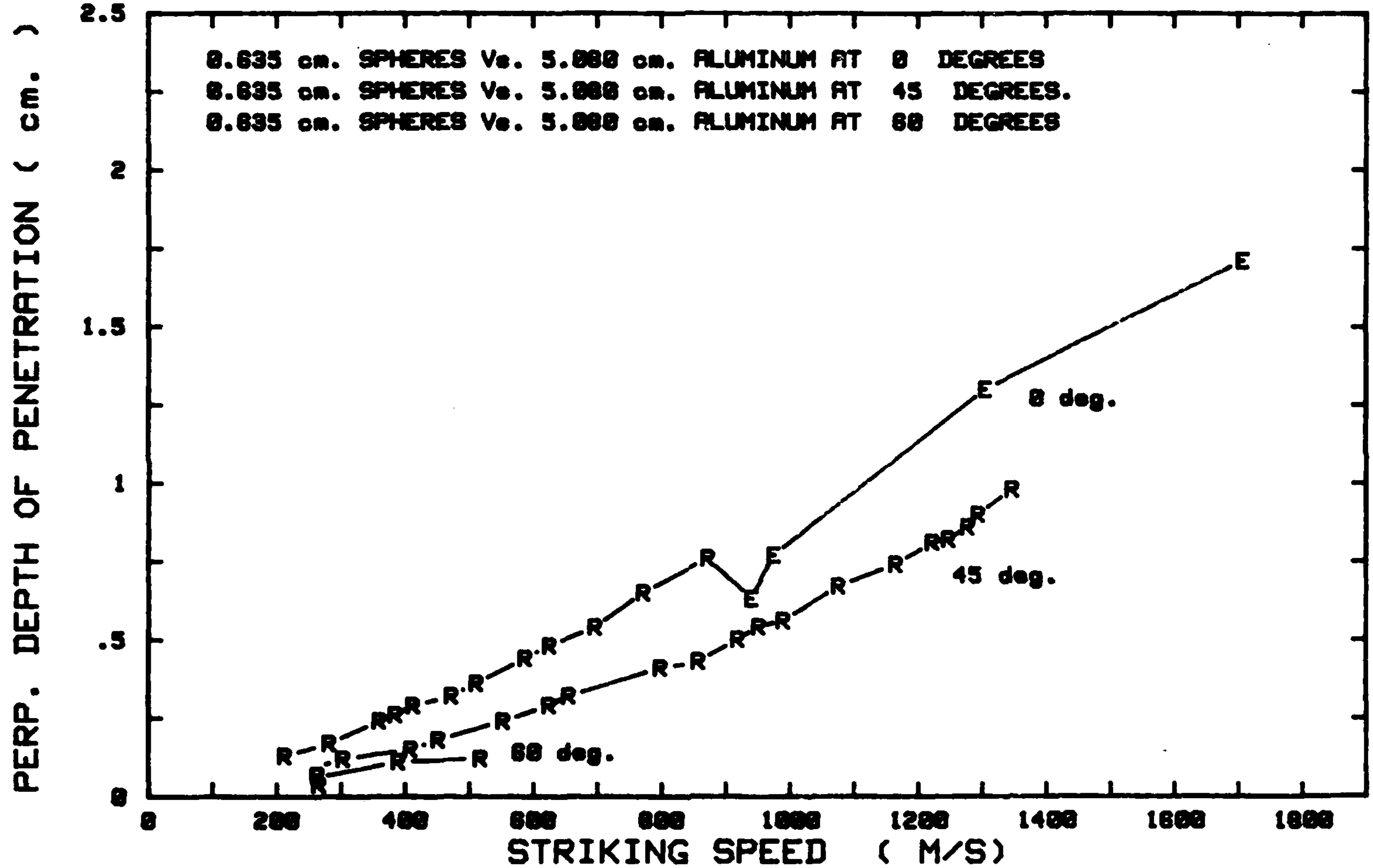


FIGURE 20 Perpendicular Depth Versus Striking Speed For 1/4 Inch Steel Spheres Impacting 2 Inch Aluminum Targets At Three Impact Angles

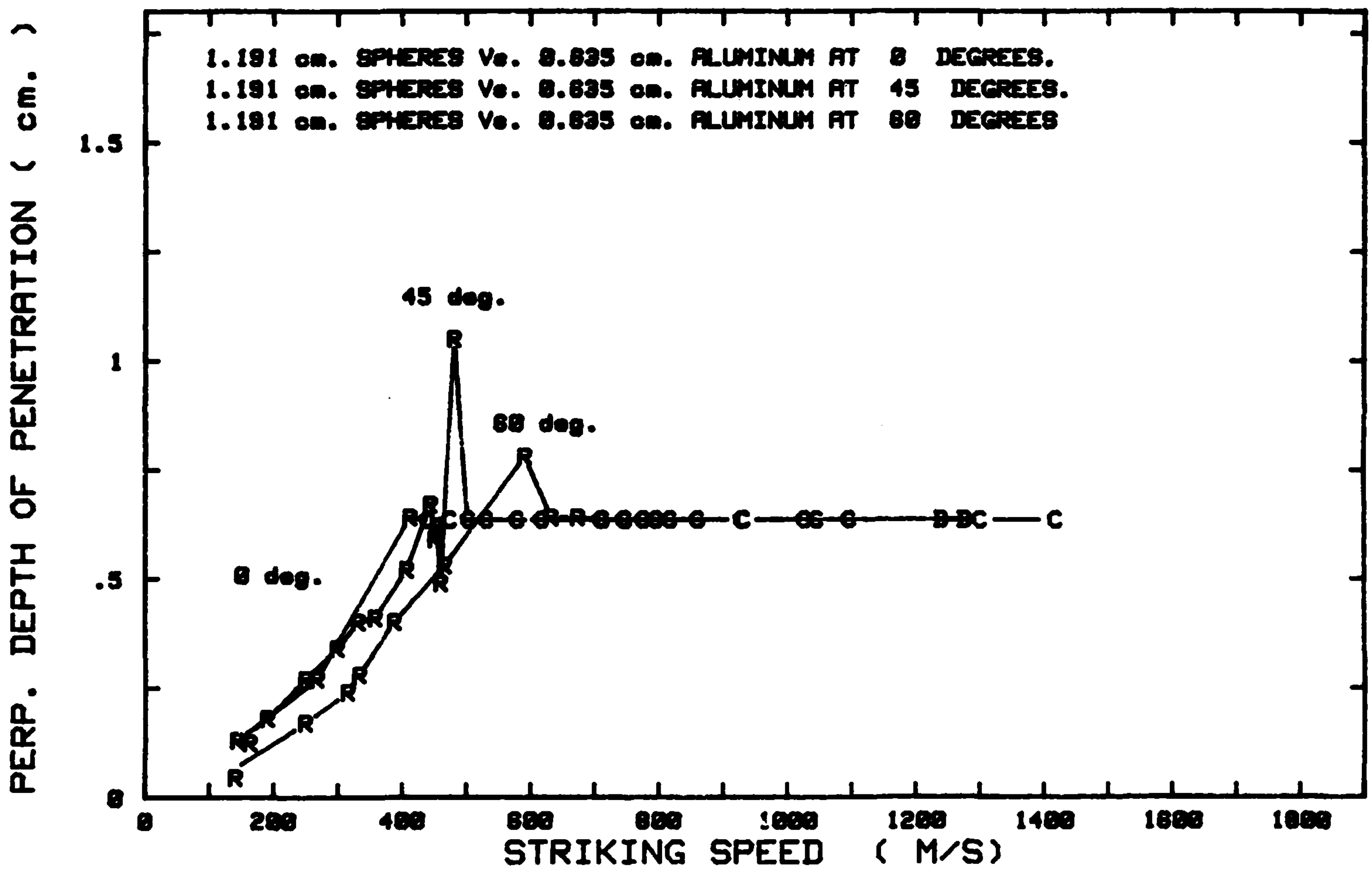


FIGURE 21 Perpendicular Depth Versus Striking Speed For 15/32 Inch Steel Spheres Impacting 1\4 Inch Aluminum Targets At Three Impact Angles

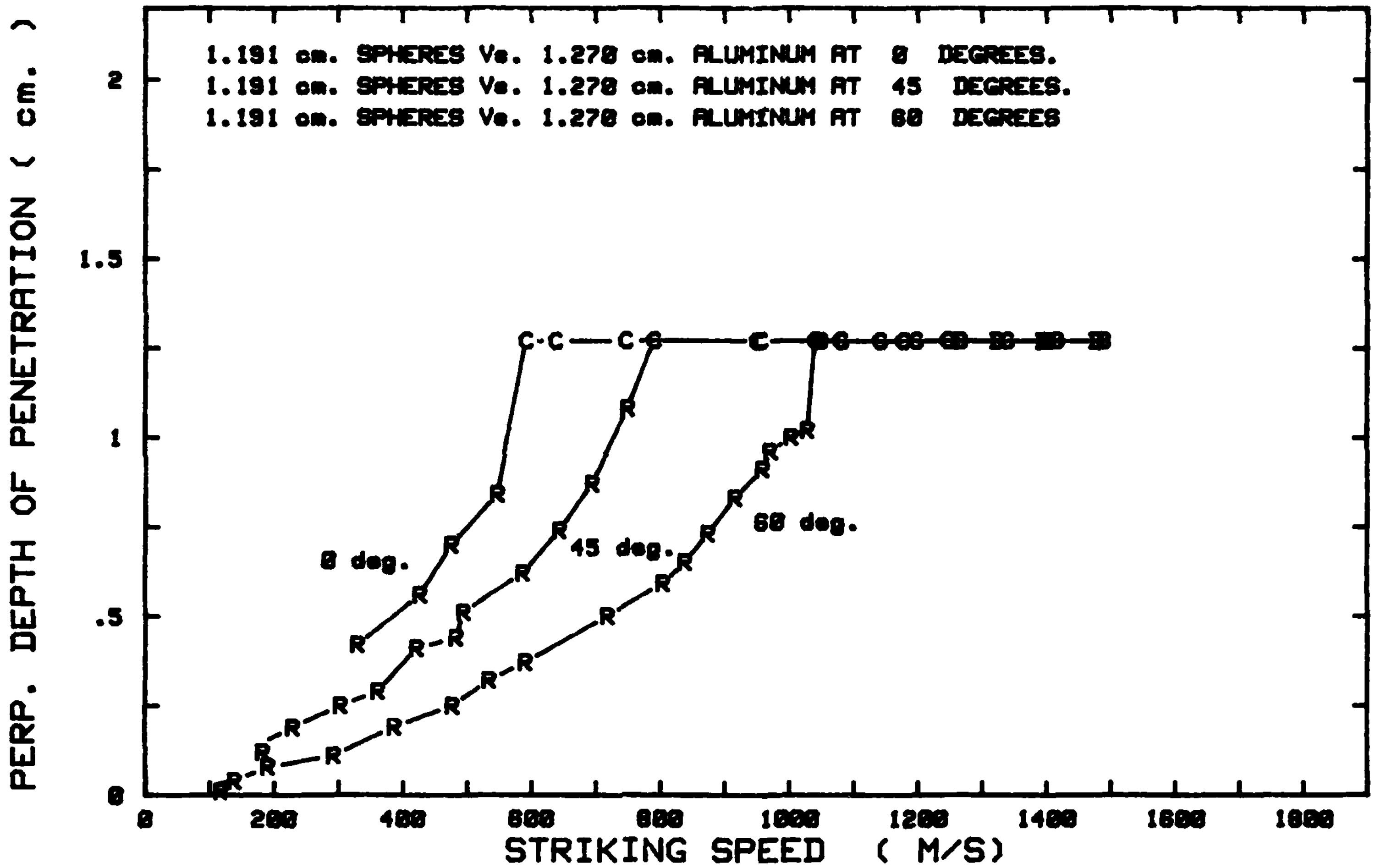


FIGURE 22 Perpendicular Depth Versus Striking Speed For 15/32 Inch Steel Spheres Impacting 1\2 Inch Aluminum Targets At Threw Impact Angles

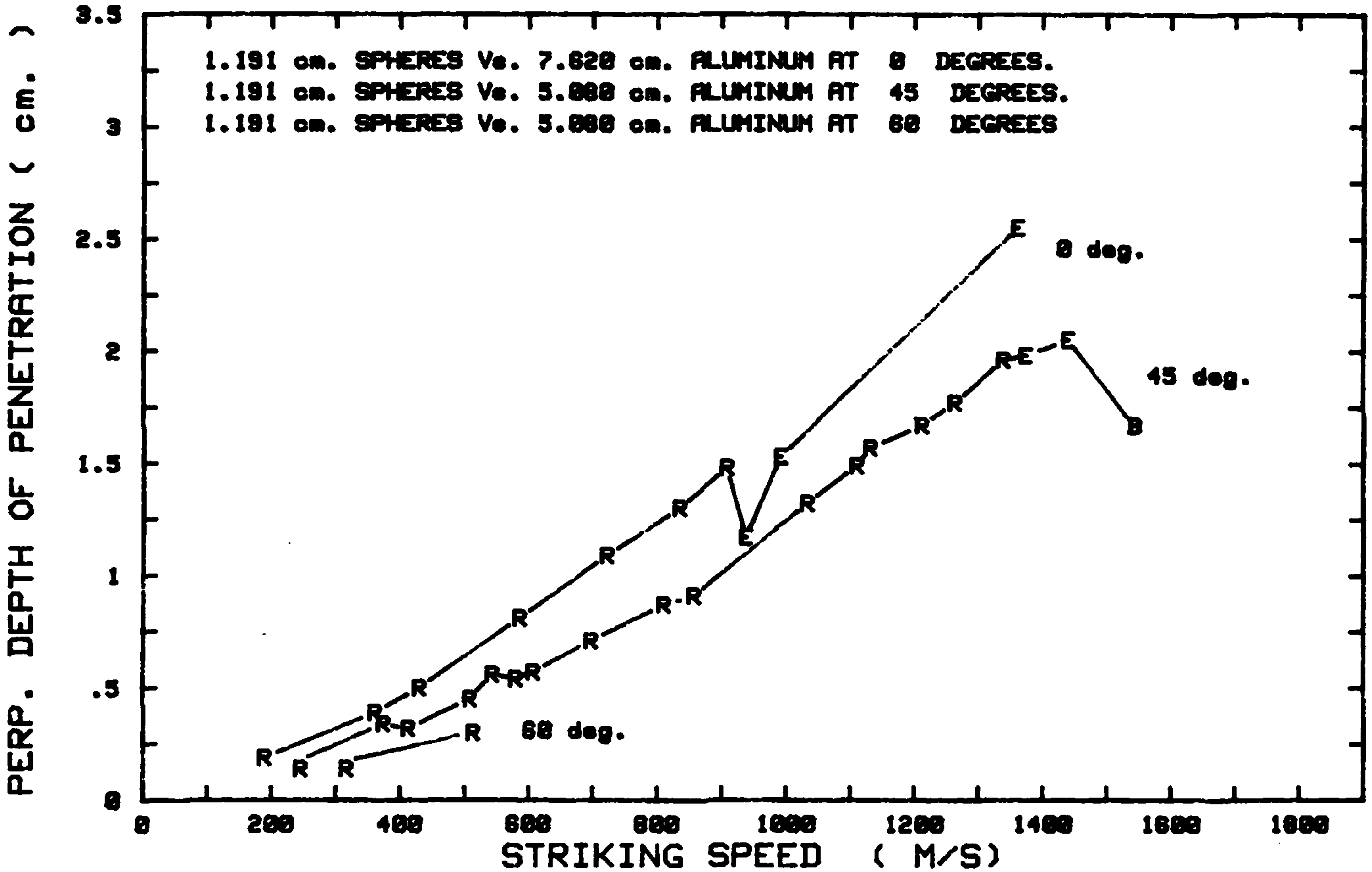


FIGURE 23 Perpendicular Depth Versus Striking Speed For 15\32 Inch Steel Spheres Impacting 2 (or 3) Inch Aluminum Targets At Three Impact Angles

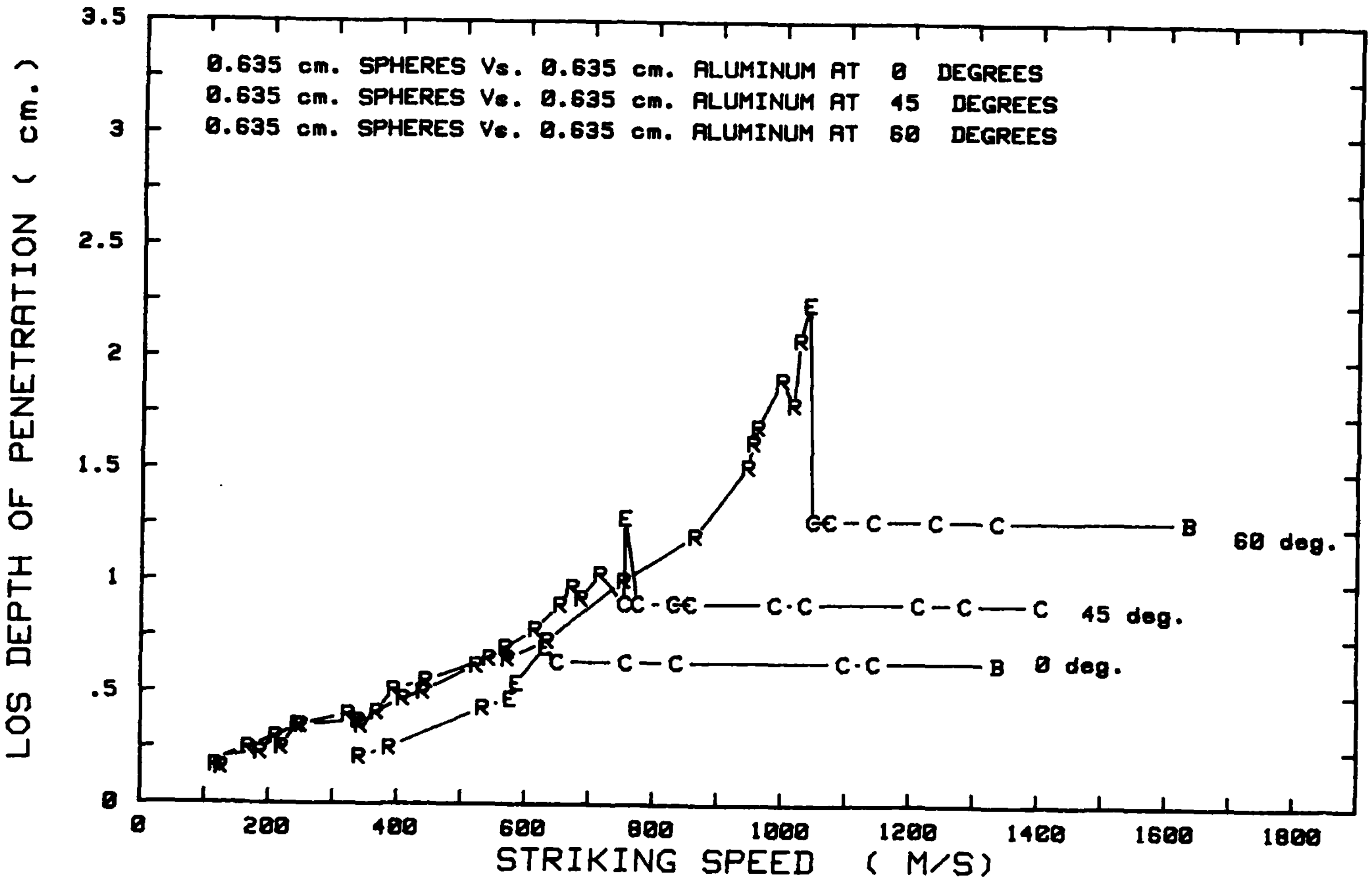


FIGURE 24 LOS Depth Versus Striking Speed For 1/4 Inch Steel Spheres Impacting 1/4 Inch Aluminum Targets At Three Impact Angles

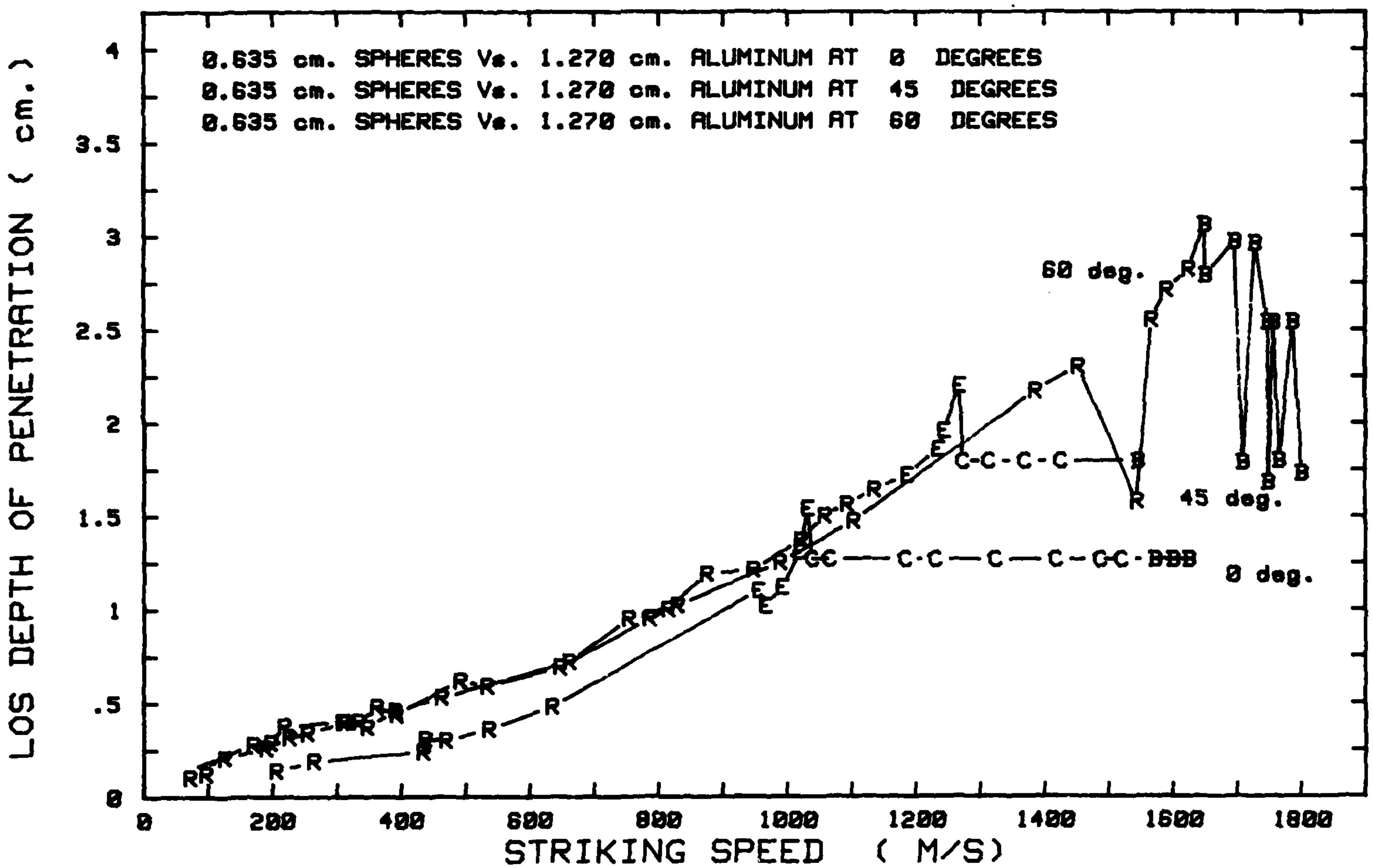


FIGURE 25 LOS Depth Versus Striking Speed For 1/4 Inch Steel Spheres Impacting 1/2 Inch Aluminum Targets At Three Impact Angles

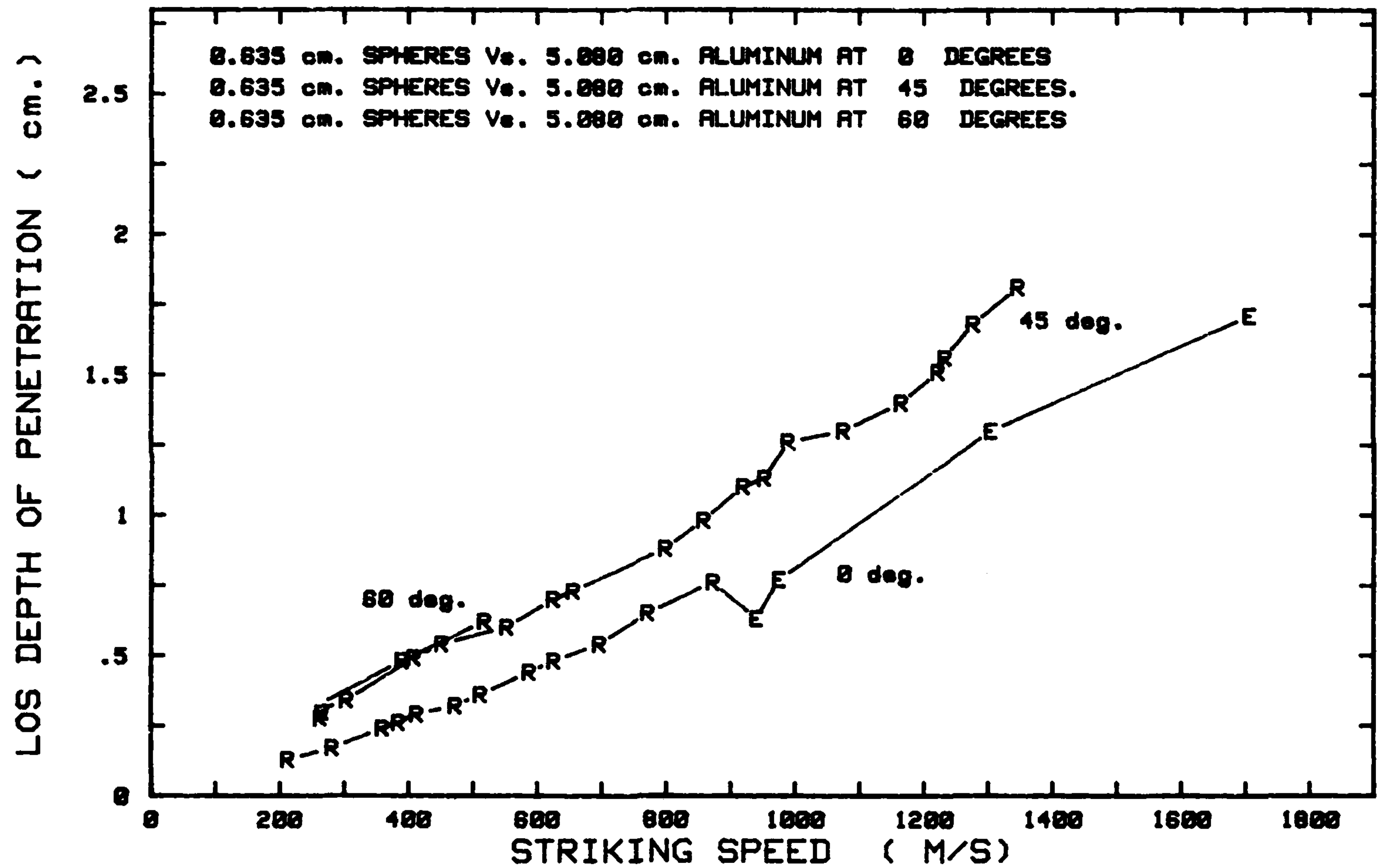


FIGURE 26 LOS Depth Versus Striking Speed For 1/4 Inch Steel Spheres Impacting 2 Inch Aluminum Targets At Three Impact Angles

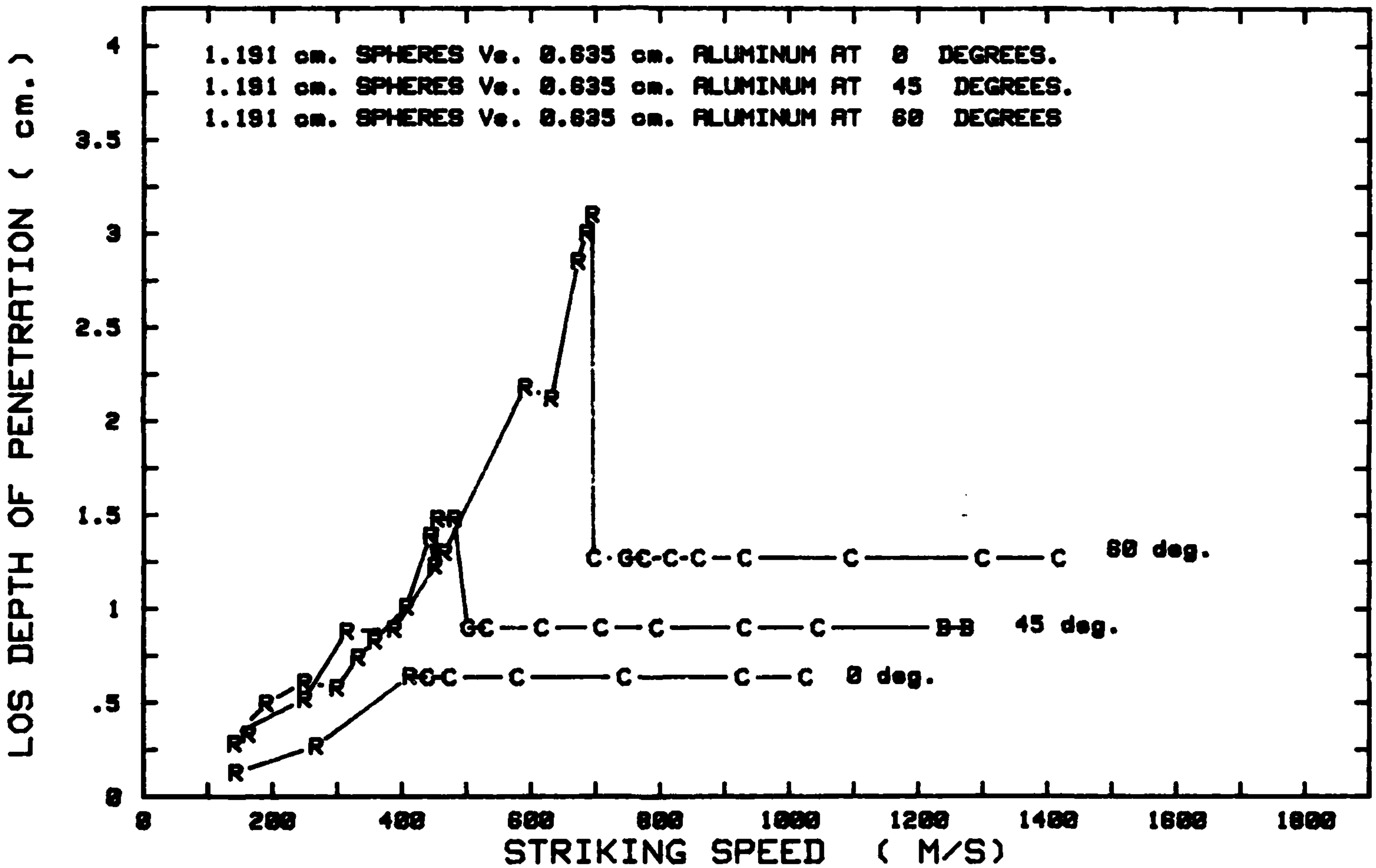


FIGURE 27 LOS Depth Versus Striking Speed For 15/32 Inch Steel Spheres Impacting 1\4 Inch Aluminum Targets At Three Impact Angles

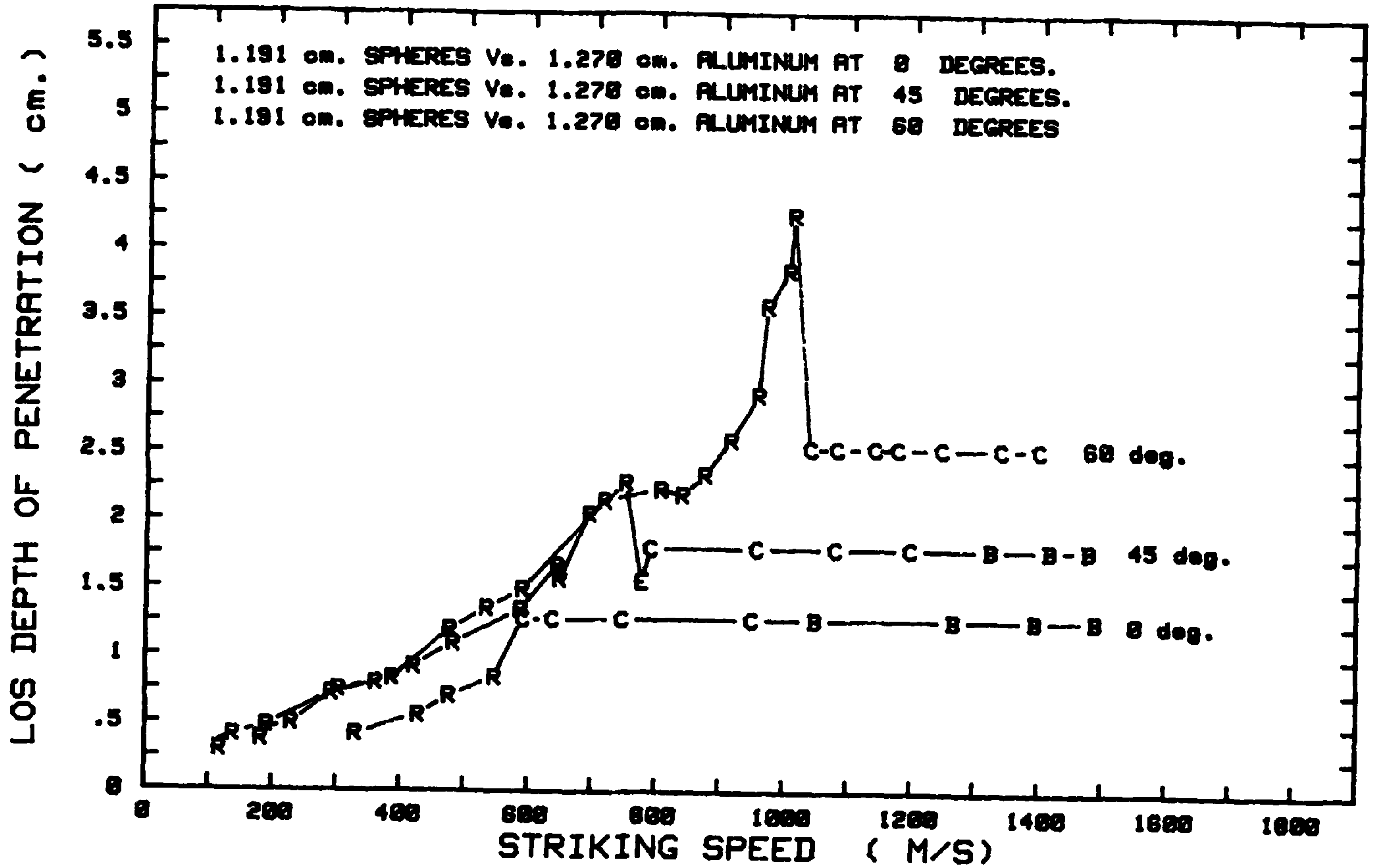


FIGURE 28 LOS Depth Versus Striking Speed For 15/32 Inch Steel Spheres Impacting 1\2 Inch Aluminum Targets At Three Impact Angles

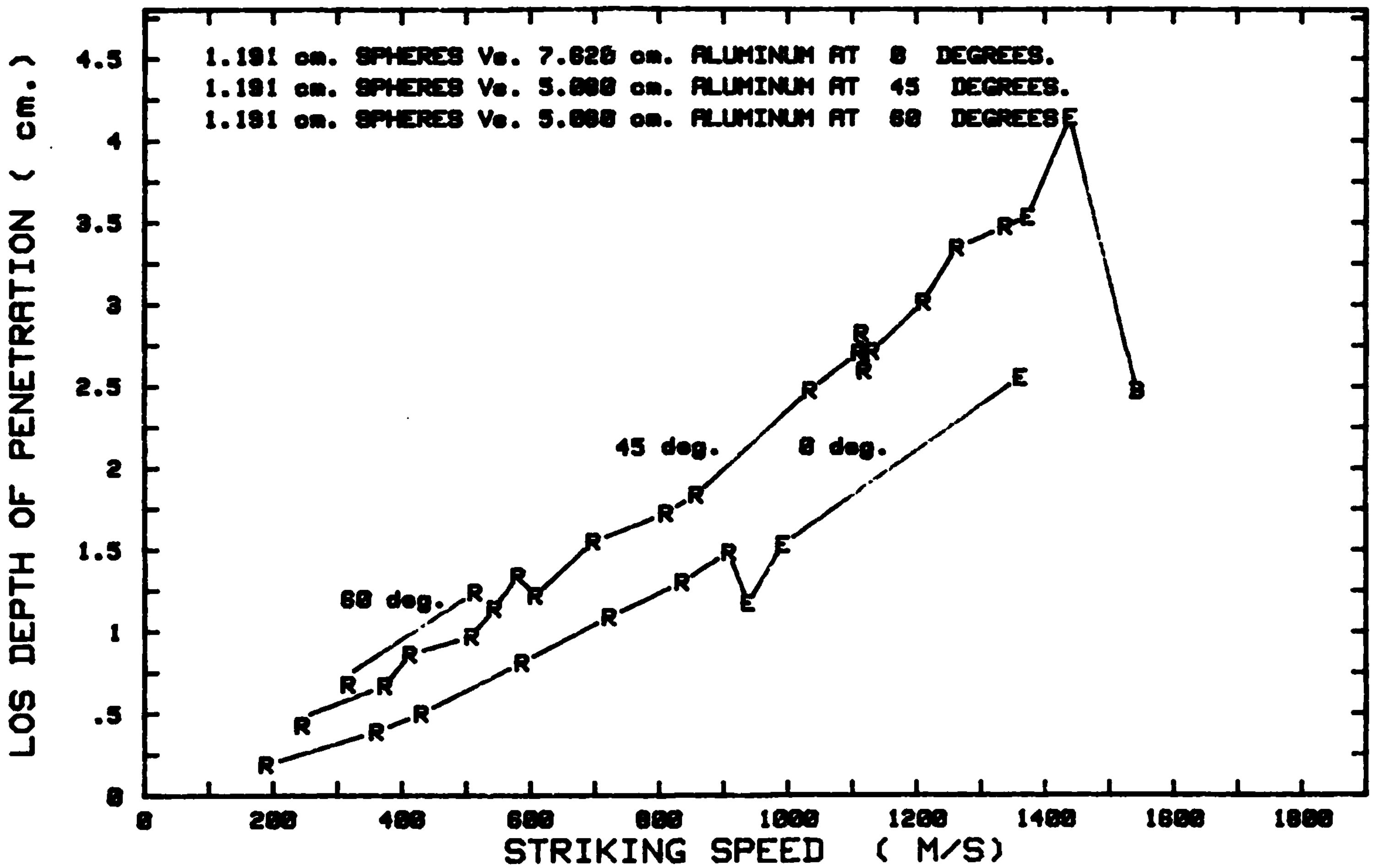


FIGURE 29 LOS Depth Versus Striking Speed For 15\32 Inch Steel Spheres Impacting 2 (or 3) Inch Aluminum Targets At Three Impact Angles

PERPENDICULAR DEPTH OF PENETRATION VERSUS STRIKING SPEED

Plots of the perpendicular depth of penetration as functions of the striking speed for the 1/4 inch sphere are presented in Figures 18 through 20. Similar data for the 15/32 inch diameter sphere are presented in Figures 21 through 23. Based on all of these figures, the perpendicular depth of penetration for a given striking speed in the ricochet region decreases as the obliquity increases as might be expected.

The perpendicular depth of penetration as defined above can be greater than the thickness of the plate. For example, in Figure 19, the embedment for the 0 degree obliquity curve at the 1032 m/s striking speed resulted in the sphere being exposed on the rear surface of the target plate and the most forward point on the sphere extending approximately 0.26 cm beyond the surface of the target. The effect is also shown clearly in Figure 21 for the 1/2 inch diameter sphere at the 45 degree impact angle.

As shown in Figure 20 and Figure 23, the perpendicular depth of penetration for some of the curves appears to decrease at the onset of embedment and then increases again at higher striking speeds. This decrease is probably not actual because in the experiments where the spheres embedded in the plate, the diameter of the sphere was added to the measured value to obtain the plotted value. In those cases, the sphere more than likely was in the process of ricocheting when it was trapped, thus leaving space beneath the sphere which could not be added since it could not be measured. As shown in Figure 23, when breakup occurs for a striking speed in the embedment region, the depth of penetration is reduced and the sphere fragments ricochet.

LOS DEPTH OF PENETRATION VERSUS STRIKING SPEED

The LOS depth of penetration curves in the ricochet region are nearly identical for the 45 and 60 degree obliquities. For normal impact, the LOS depth is always less than that at oblique angle impacts for a given striking speed. Similarly to the perpendicular depth, the LOS depth can exceed the LOS plate thickness when embedment occurs and for the same reason.

III.2 RELATIONSHIPS BETWEEN SPHERE/TARGET CONFIGURATIONS

The following analysis of the penetration model (Z/F equation) reported in Reference 1 will show that the residual speed versus striking speed curves for sphere target combinations where the line-of-sight target thickness to sphere diameter ratio (LOS/D) is held constant can be expected to follow the same path (i.e., the curves will scale). The form of the Z/F equation is:

$$X_t = \frac{M_p}{2A_pK_2}\left[\ln\left(\frac{K_1 + K_2V_s + K_3V_s^2}{K_1 + K_2V_r + K_3V_r^2}\right) + \frac{2K_2}{Q}\left\{\mathrm{Tan}^{-1}\left(\frac{2K_3V_r + K_2}{Q}\right) - \mathrm{Tan}^{-1}\left(\frac{2K_3V_s + K_2}{Q}\right)\right\}\right], \quad (1)$$

where: X_t = target thickness, M_p = penetrator mass, A_p = penetrator presented area, $K_1 = C_1 H_t$, $K_2 = C_2\sqrt{\rho_t H_t}$, $K_3 = C_3 \rho_t$, $Q = \sqrt{4K_1K_3 - K_2^2}$, H_t = target Brinell hardness x 9.8E7, ρ_t = target density, V_s = striking speed, V_r = residual speed and C_1, C_2 and C_3 are empirical constants.

This equation was derived only for normal impacts where the striking speed is high enough to yield complete penetration and requires that the value for Q be greater than zero. It has been determined that calculations based on oblique impact data in the complete penetration region closely approximates the line-of-sight thickness using the same constants resulting from normal impact data analysis. That is, the plate thickness X_t can be replaced by the line-of-sight thickness: LOS = X_t Sec(θ) where θ is the angle of obliquity. Therefore, Equation 1 can be reduced to:

$$LOS = (M_p/A_p)\ f(V_s, V_r). \qquad (2)$$

By using the equations $M_p = \rho_p \pi D^3/6$ and $A_p = \pi D^2/4$ where ρ_p is the sphere density, noting that the target density for the data in this report is constant and that the target hardness which varies from BHN 143 to BHN 163 can be considered constant allows Equation 2 to be further reduced to:

$$LOS/D = f(V_s, V_r), \qquad (3)$$

where the constants have been incorporated into the function and both sides divided by D. It is evident from Equation 3 that when the LOS and D are varied such that LOS/D remains constant, the same residual speed will result from any given striking speed.

Table 1 lists the LOS/D ratios for the sphere/target combinations fired in this program. Based on these ratios, the following comparisons verify the relationship indicated in Equation 3 and also shows that, for constant obliquity, scaling occurs in the ricochet and embedment regions.

The exit speed as a function of striking velocity is plotted in Figure 30 for three cases. The LOS/D is 1.0 for the 1/4 inch sphere and 1.067 for the two curves of the 15/32 inch diameter sphere. The one curve at sixty degrees obliquity does not scale quite as well as the two zero degree impact angle curves in the complete penetration region and not at all in the ricochet or embedment region. Also, the 15/32 inch sphere did not imbed at the sixty degrees obliquity. Considering Figure 31, where the LOS/D ratio is slightly different for the two curves, but the impact angle is the same, the curves scale quite well over all regions. In Figure 32, there are again two curves at the same obliquity (sixty degrees in this case) which scale well over all regions and one curve at zero degrees impact angle which scales only in the complete penetration region. The thickness of target for the next three plots, Figures 33 through 35, is large enough so that the target can be considered semi-infinite (i.e., no observable effect of the penetration occurs on the rear surface of the target). When the obliquity is held constant, the curves scale well for both sphere sizes.

TABLE 1 LINE-OF-SIGHT THICKNESS/SPHERE DIAMETER RATIO

SPHERE DIAMETER (cm.)	PLATE THICKNESS (cm.)	IMPACT ANGLE (OBLIQUITY)		
		0	45	60
0.635	0.635	1.000	1.414	2.000
	1.270	2.000	2.828	4.000
	5.080	INF	INF	INF
1.191	0.635	0.533	0.754	1.067
	1.270	1.067	1.508	2.133
	5.080	*	INF	INF
	7.620	INF	*	*

INF - Semi-infinite target   * - Not applicable

Although the analysis of Equation 1 does not consider scaling of other parameters, it has been observed that the exit angle, the perpendicular depth of penetration/diameter ratio and the line-of-sight depth of penetration/diameter ratio also scale when the LOS/D ratio is held constant. The following paragraphs examine Figures 36 through 53 which involve these parameters.

Comparisons of the exit angle as functions of the striking speed are presented in Figures 36 through 41 in the same sequence as Figures 30 through 35. Again the comparisons where the LOS/D are equal indicates that the data is independent of the size of the sphere. In Figure 40, the greatest deviation between the curves occurs but since the data shows large fluctuations when approaching the ballistic limit (which are probably random fluctuations), the comparison is consistent with previous observations.

Figures 42 through 47 present the comparisons of the perpendicular depth of penetration as a function of striking speed and Figures 48 through 53 present the comparisons of the LOS/D depth of penetration. In these comparisons, the data are shown to be independent of the sphere size.

An indication of how well Equation 1 represents the sphere data can be seen in Figures 54 through 56. The empirical constants were evaluated using the same non-linear least squares program used in Reference 1 but based on the sphere residual speed for normal impacts in the complete penetration

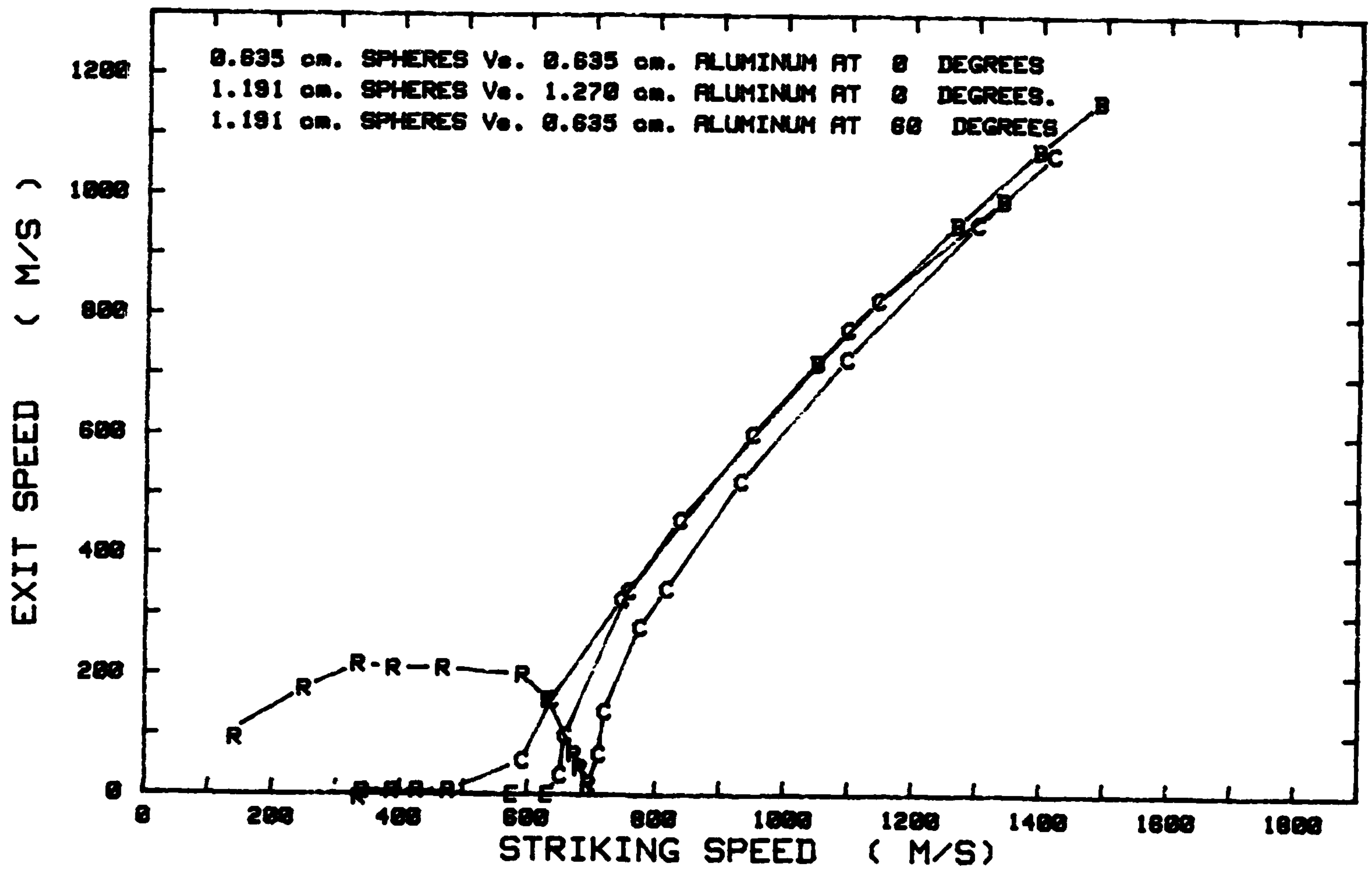


FIGURE 30 Exit Speed Versus Striking Speed For LOS/D = 1.000 or 1.067

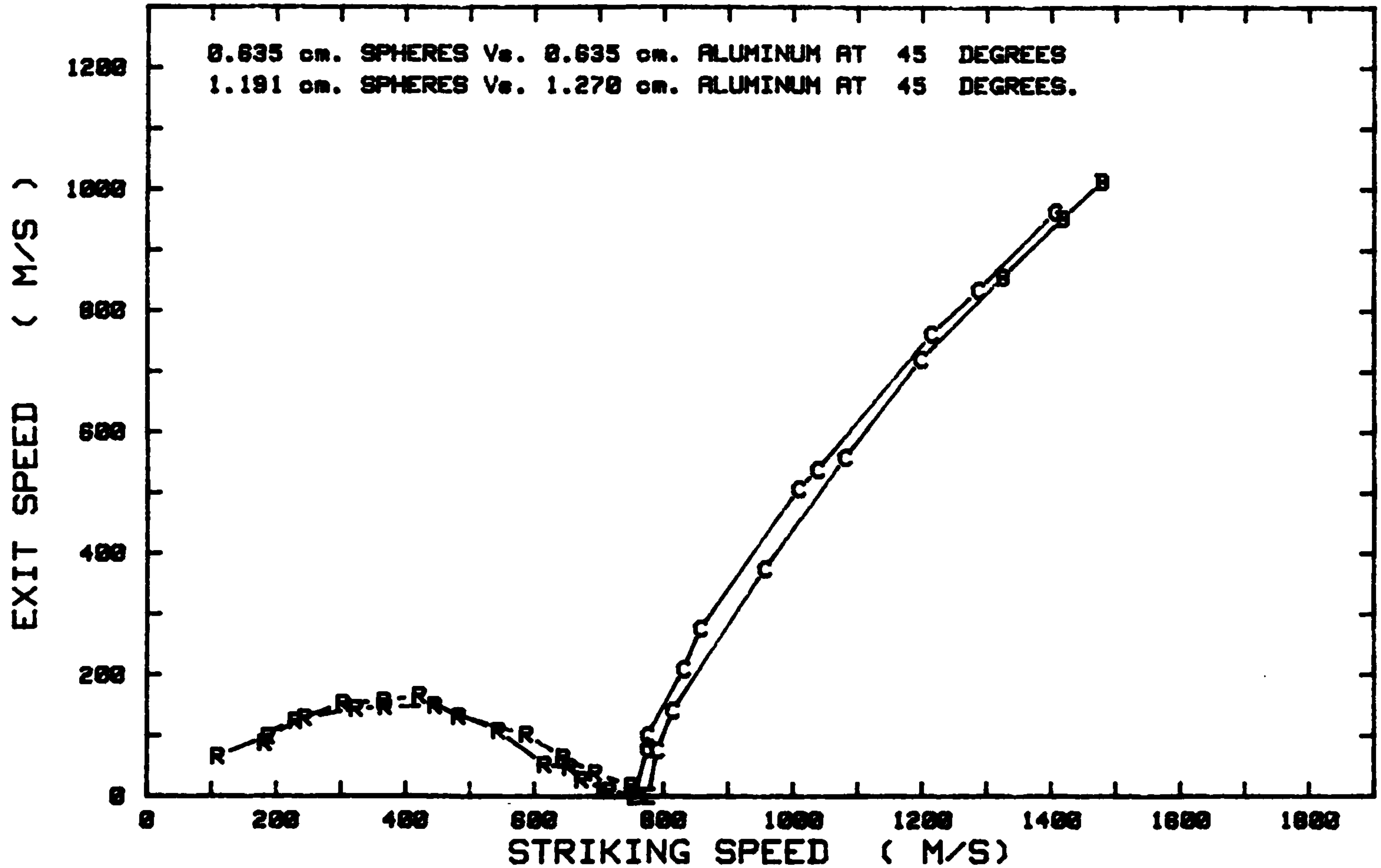


FIGURE 31 Exit Speed Versus Striking Speed For LOS/D =1.414 or 1.500

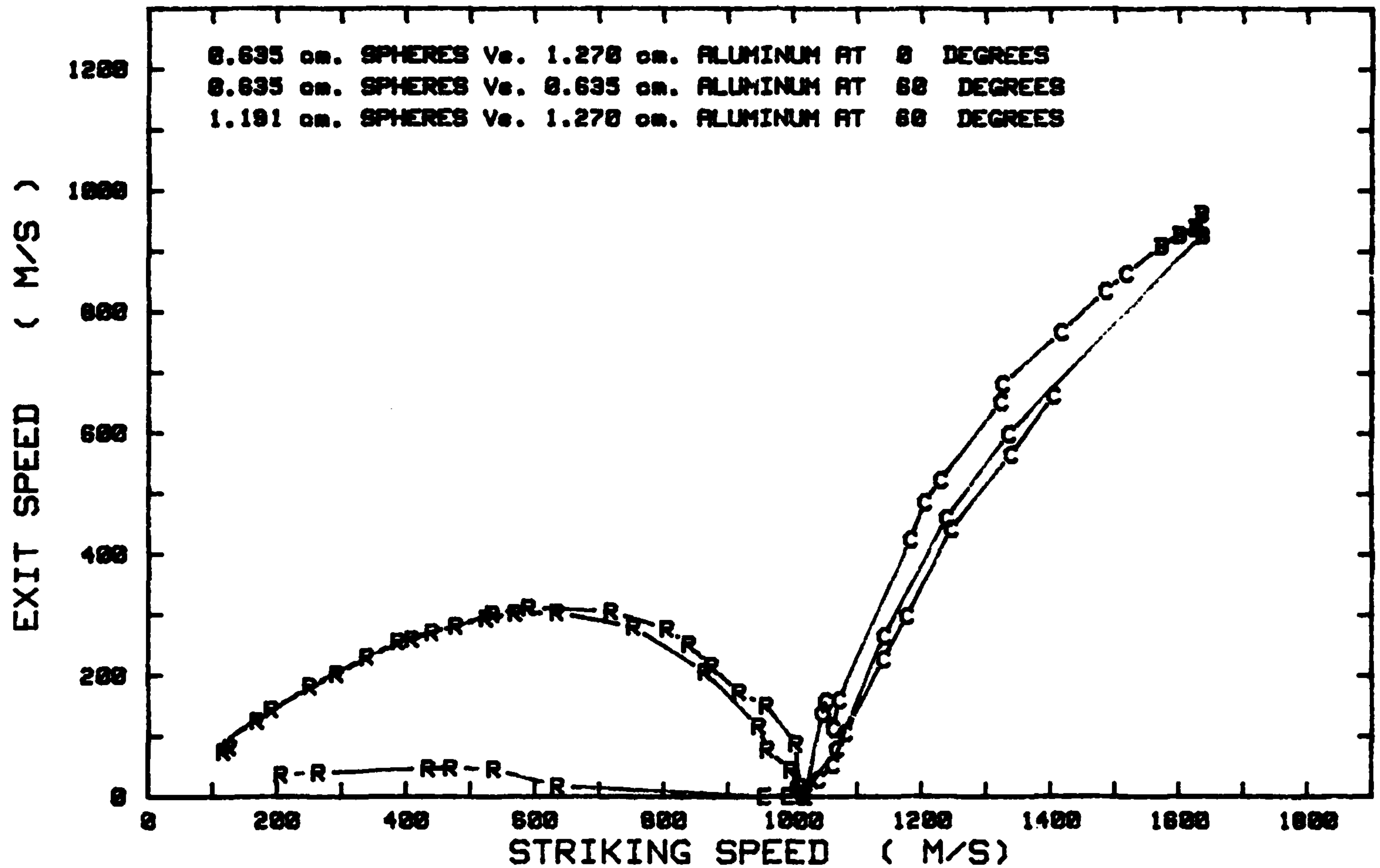


FIGURE 32 Exit Speed Versus Striking Speed For LOS/D =2.000 or 2.133

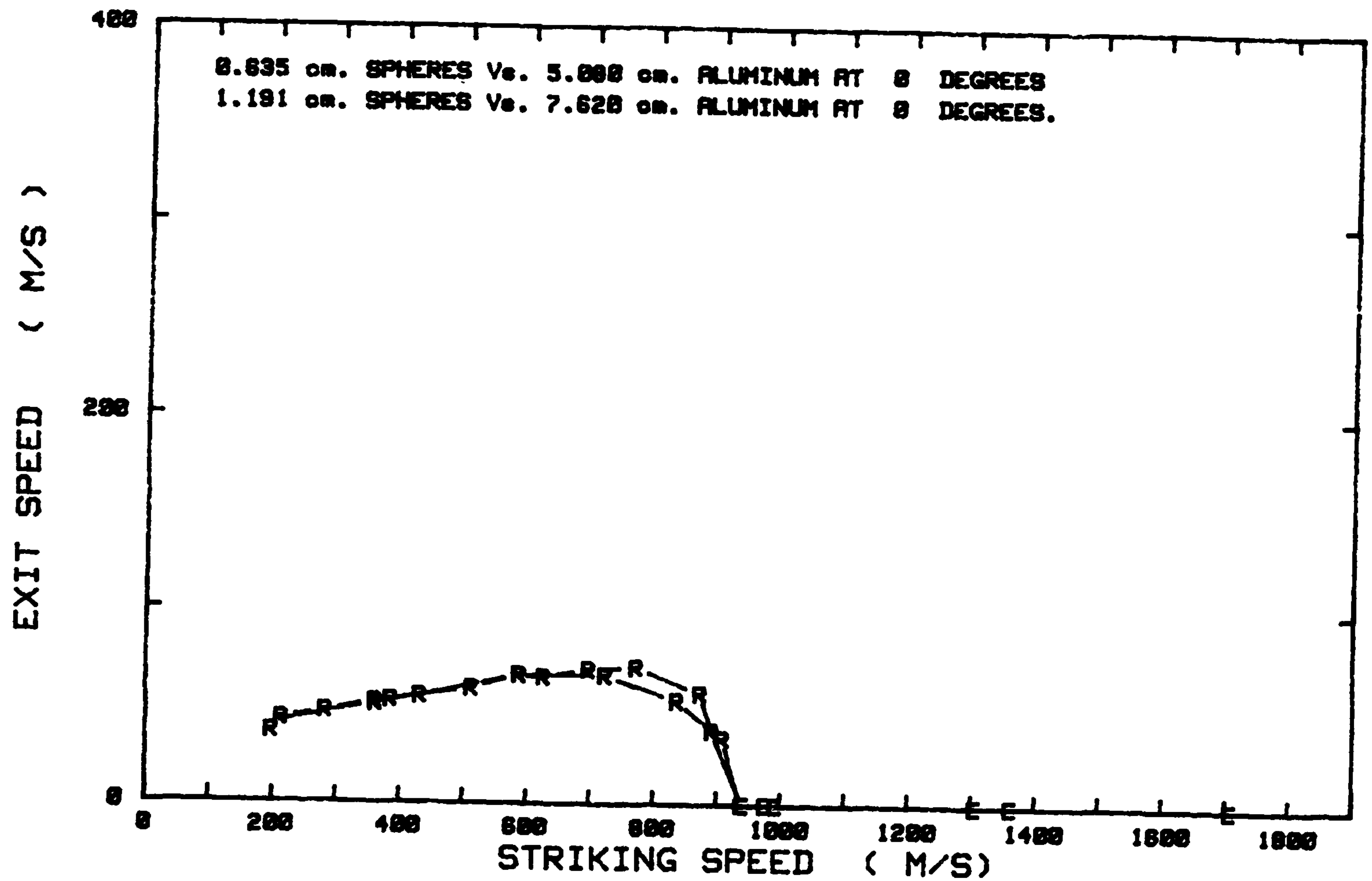


FIGURE 33 Exit Speed Versus Striking Speed For LOS/D = 'INF' at 0 deg.

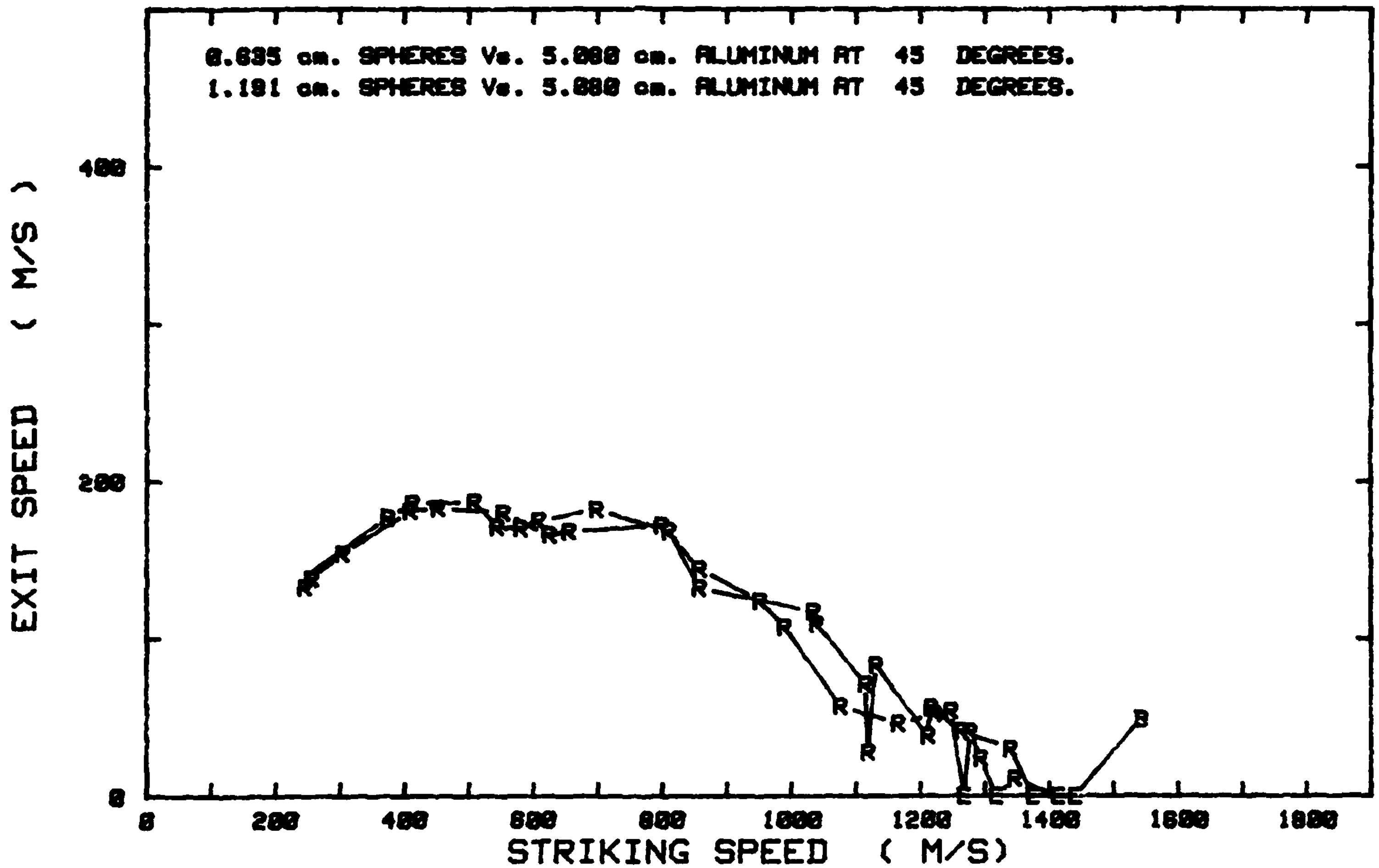


FIGURE 34 Exit Speed Versus Striking Speed For LOS/D = 'INF' at 45 deg.

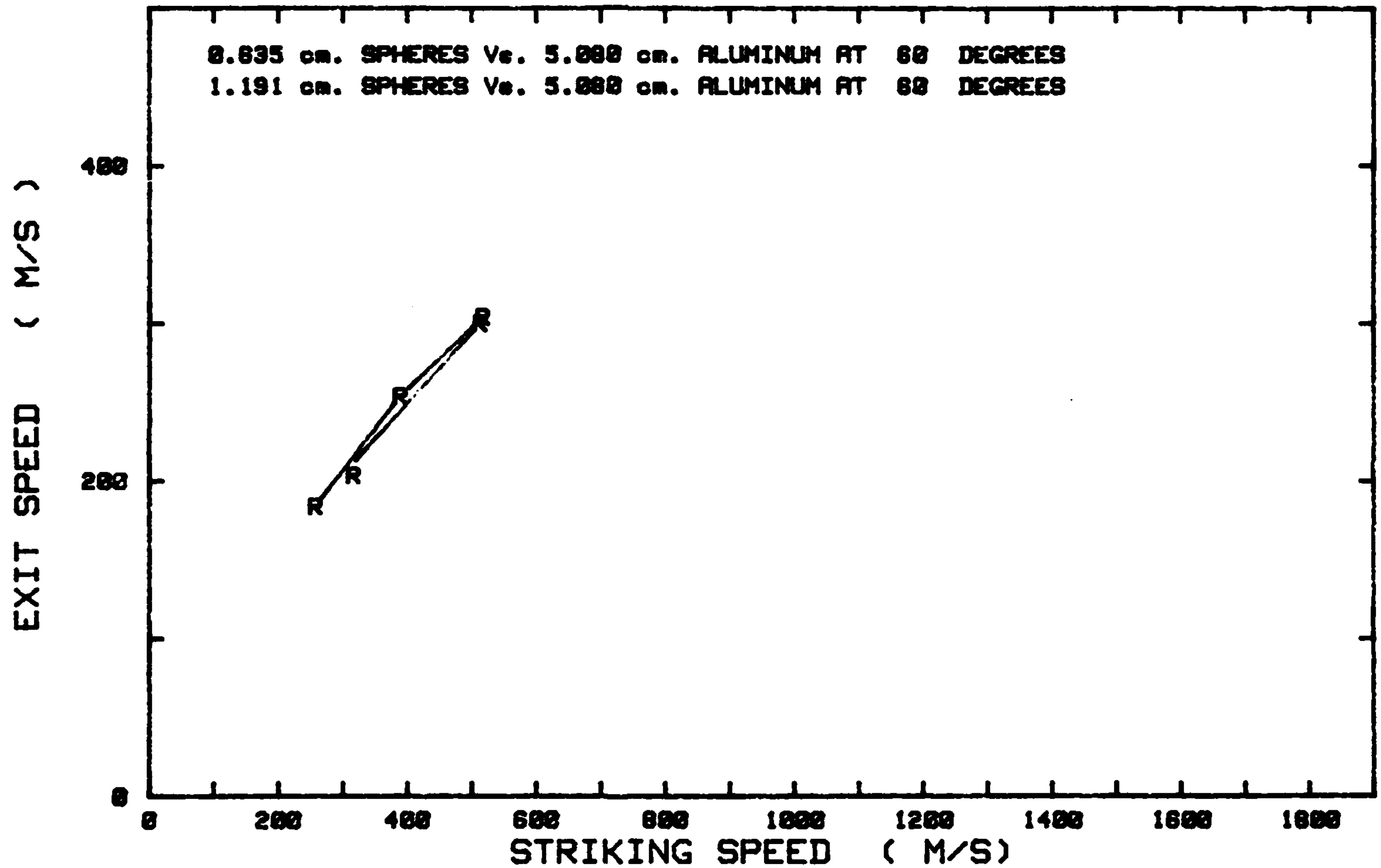


FIGURE 35 Exit Speed Versus Striking Speed For LOS/D = 'INF' at 60 deg.

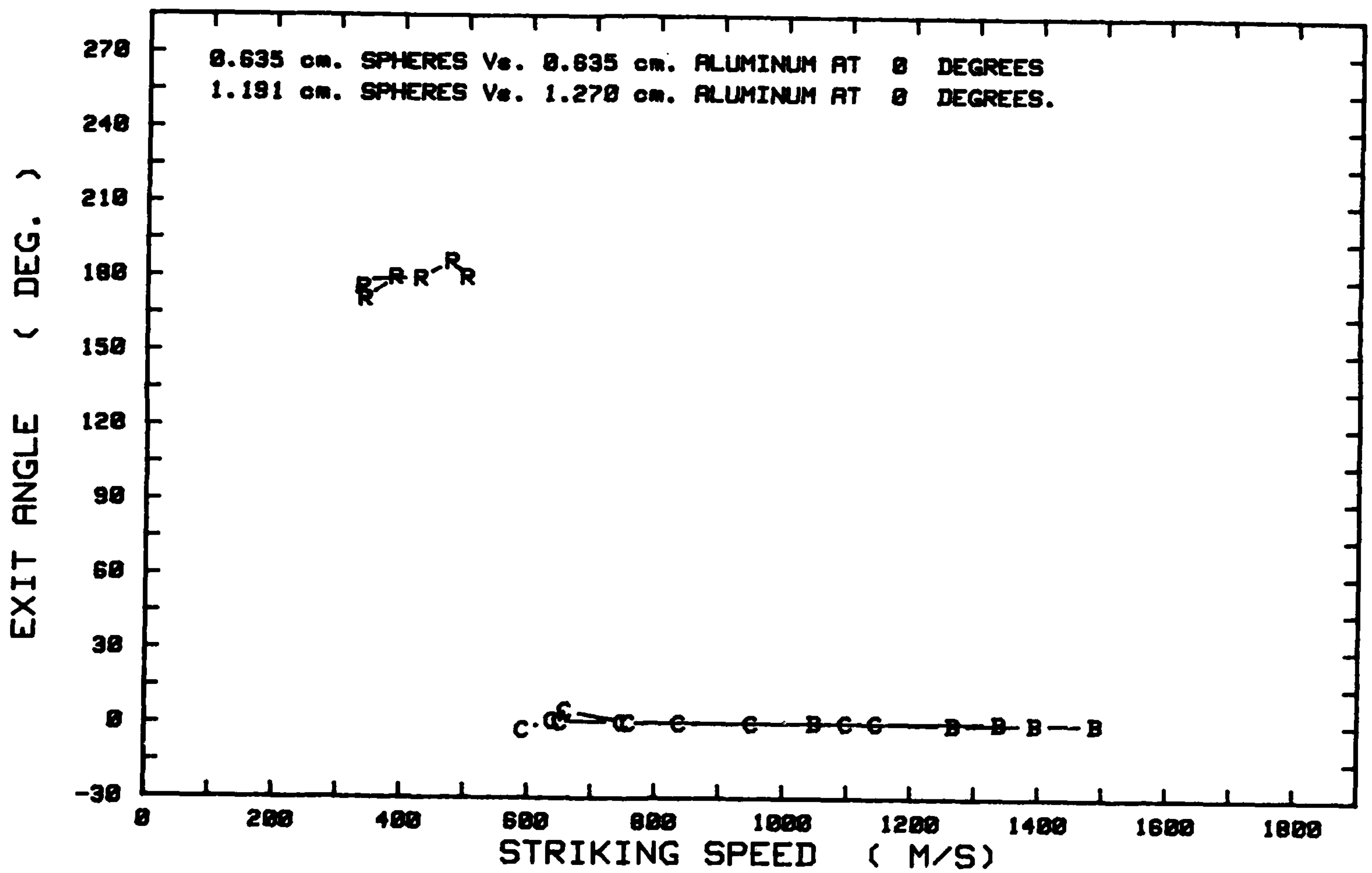


FIGURE 36 Exit Angle Versus Striking Speed For LOS/D = 1.000 or 1.067

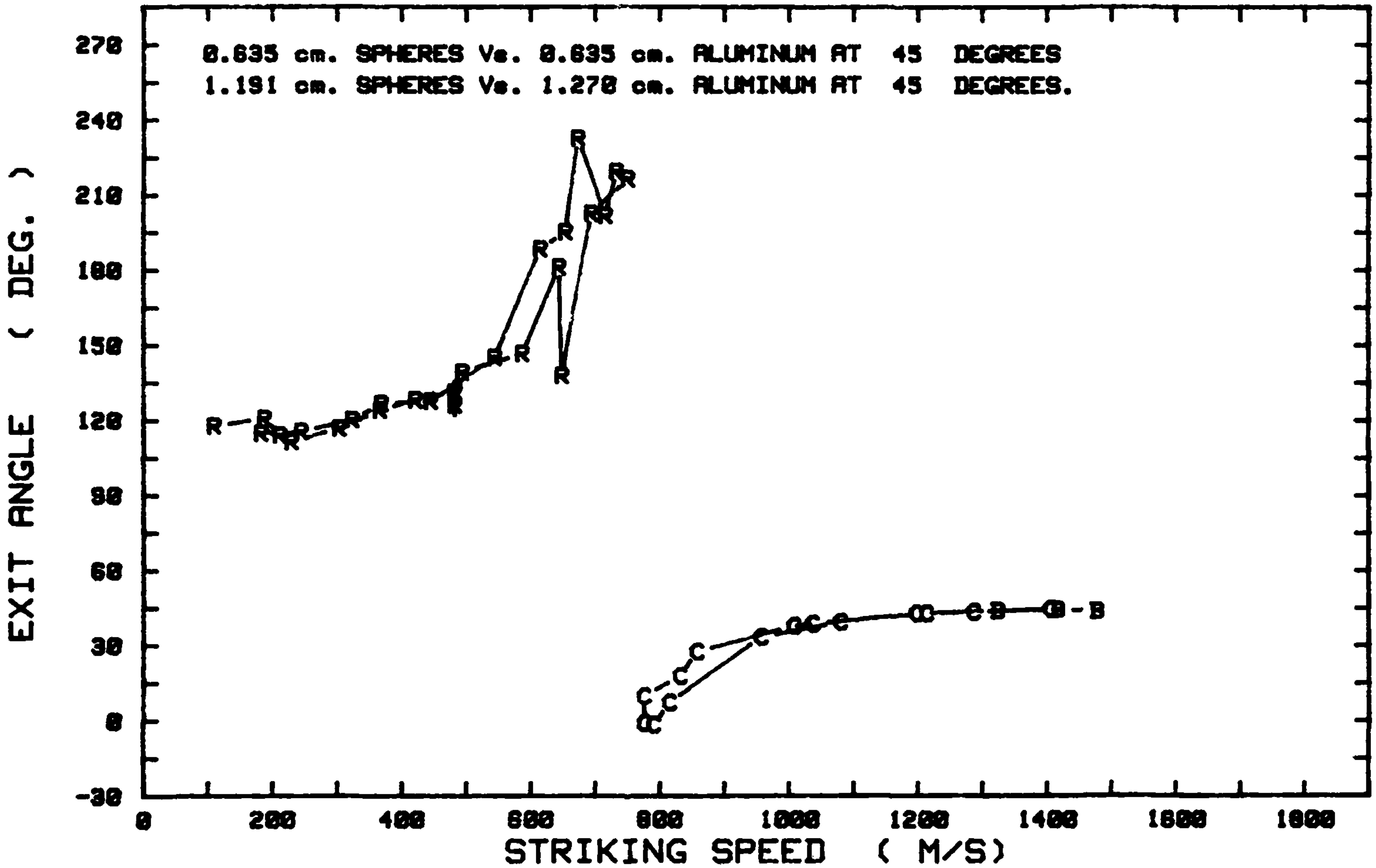


FIGURE 37 Exit Angle Versus Striking Speed For LOS/D =1.414 or 1.508

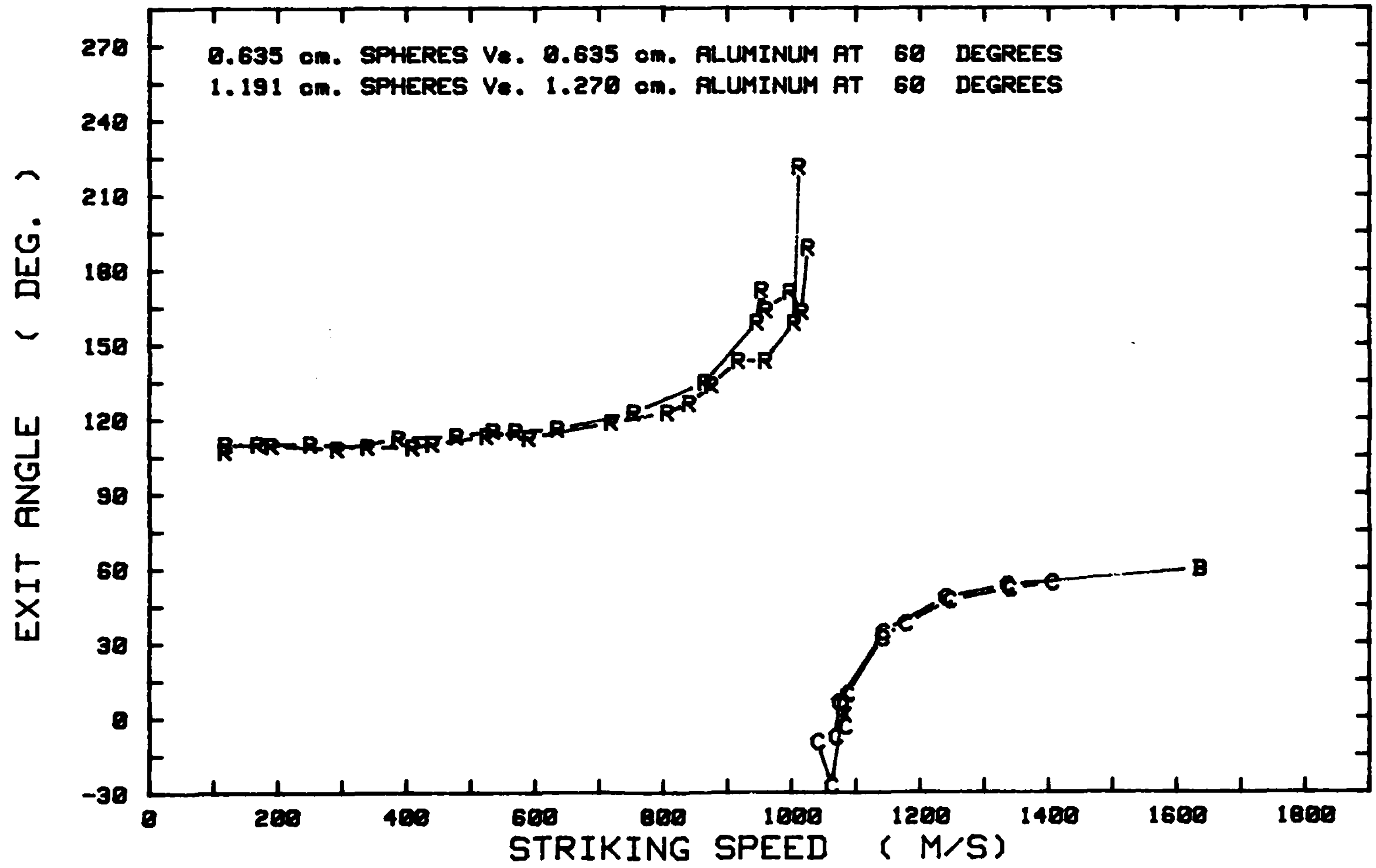


FIGURE 38 Exit Angle Versus Striking Speed For LOS/D = 2.000 or 2.133

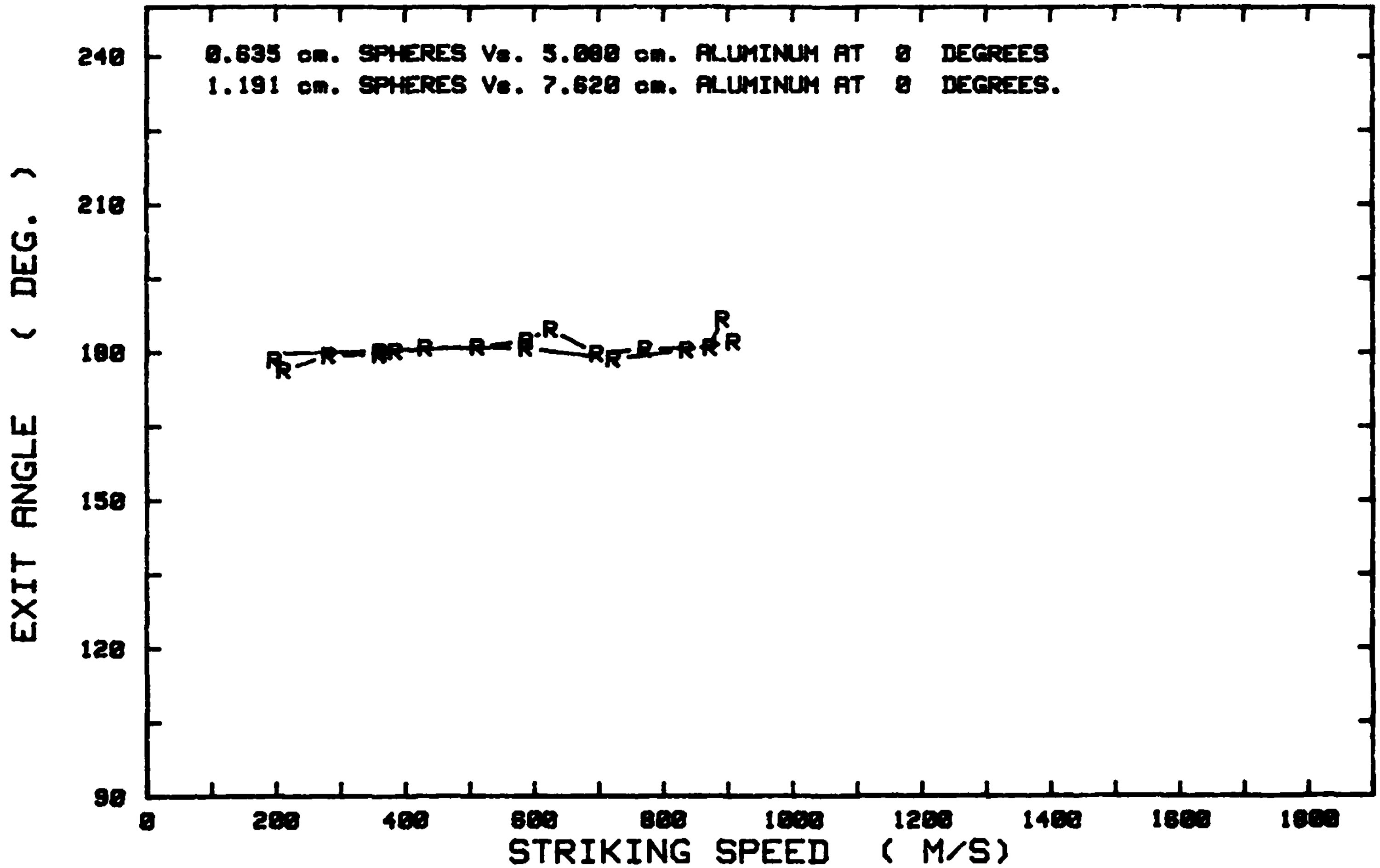


FIGURE 39 Exit Angle Versus Striking Speed For LOS/D = 'INF' at 0 deg.

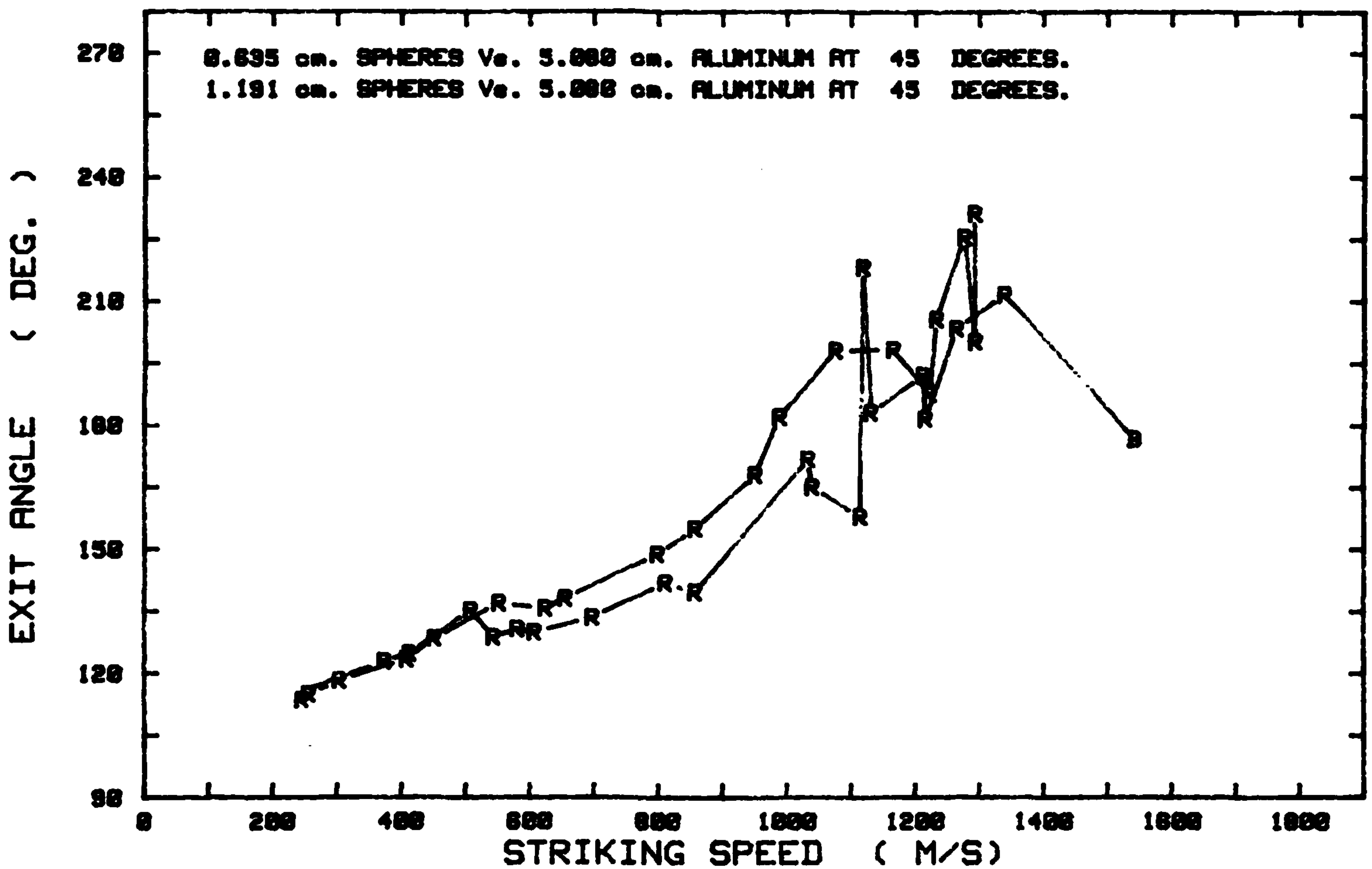


FIGURE 40 Exit Angle Versus Striking Speed For LOS/D = 'INF' at 45 deg.

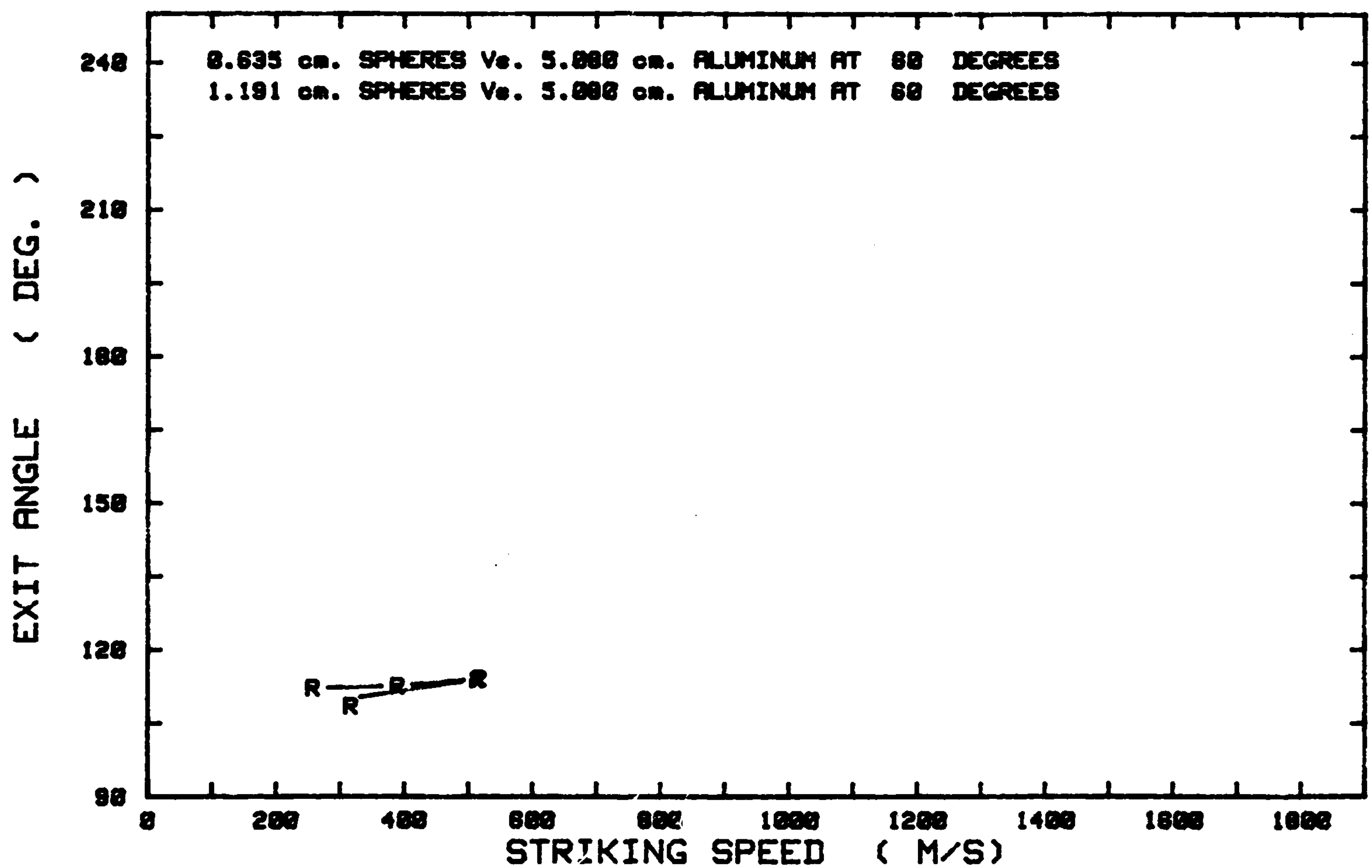


FIGURE 41 Exit Angle Versus Striking Speed For LOS/D = 'INF' at 60 deg.

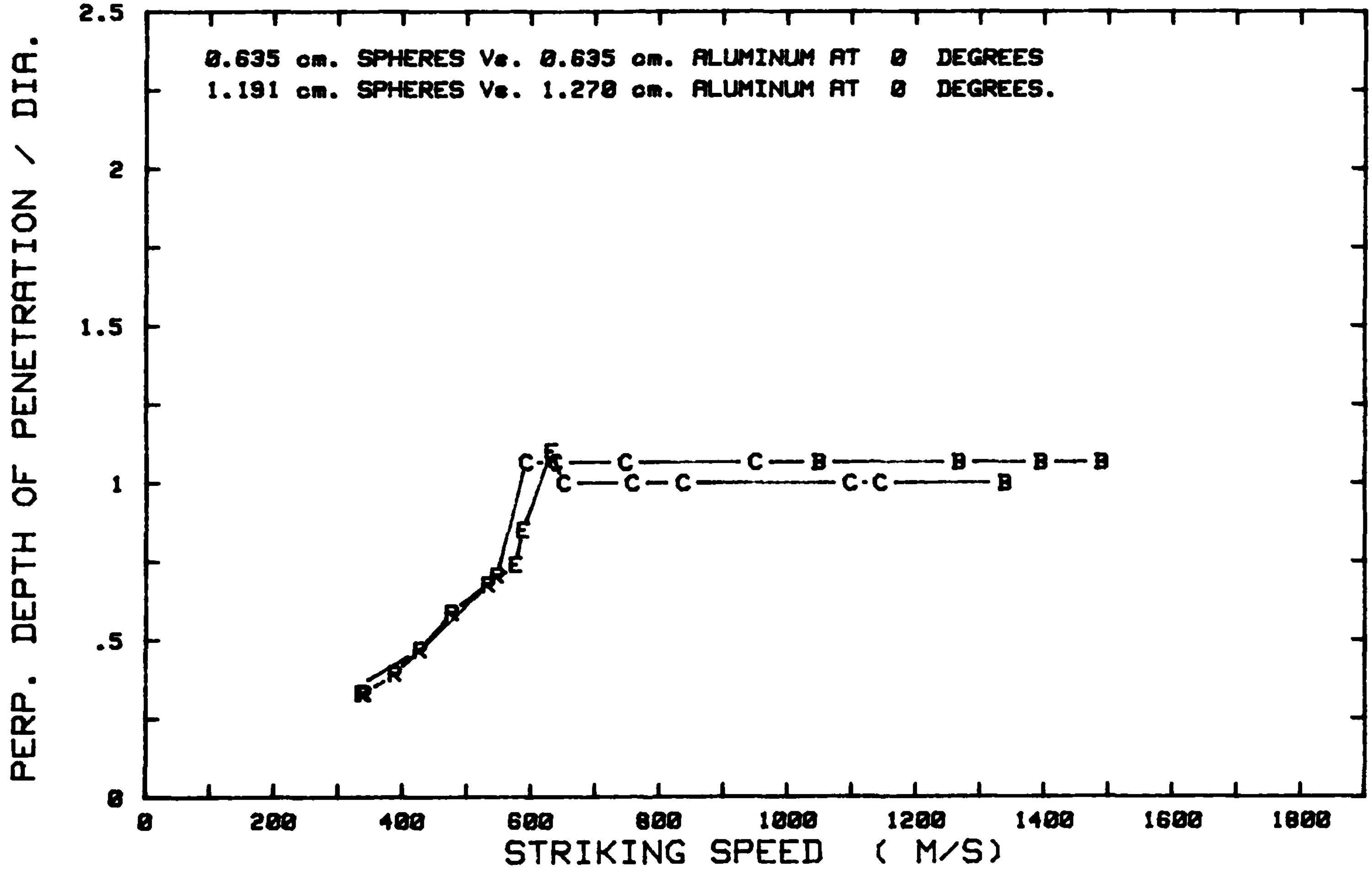


FIGURE 42 Ratio of Perp. Depth/Dia. Versus Striking Speed
For LOS/D = 1.000 or 1.067

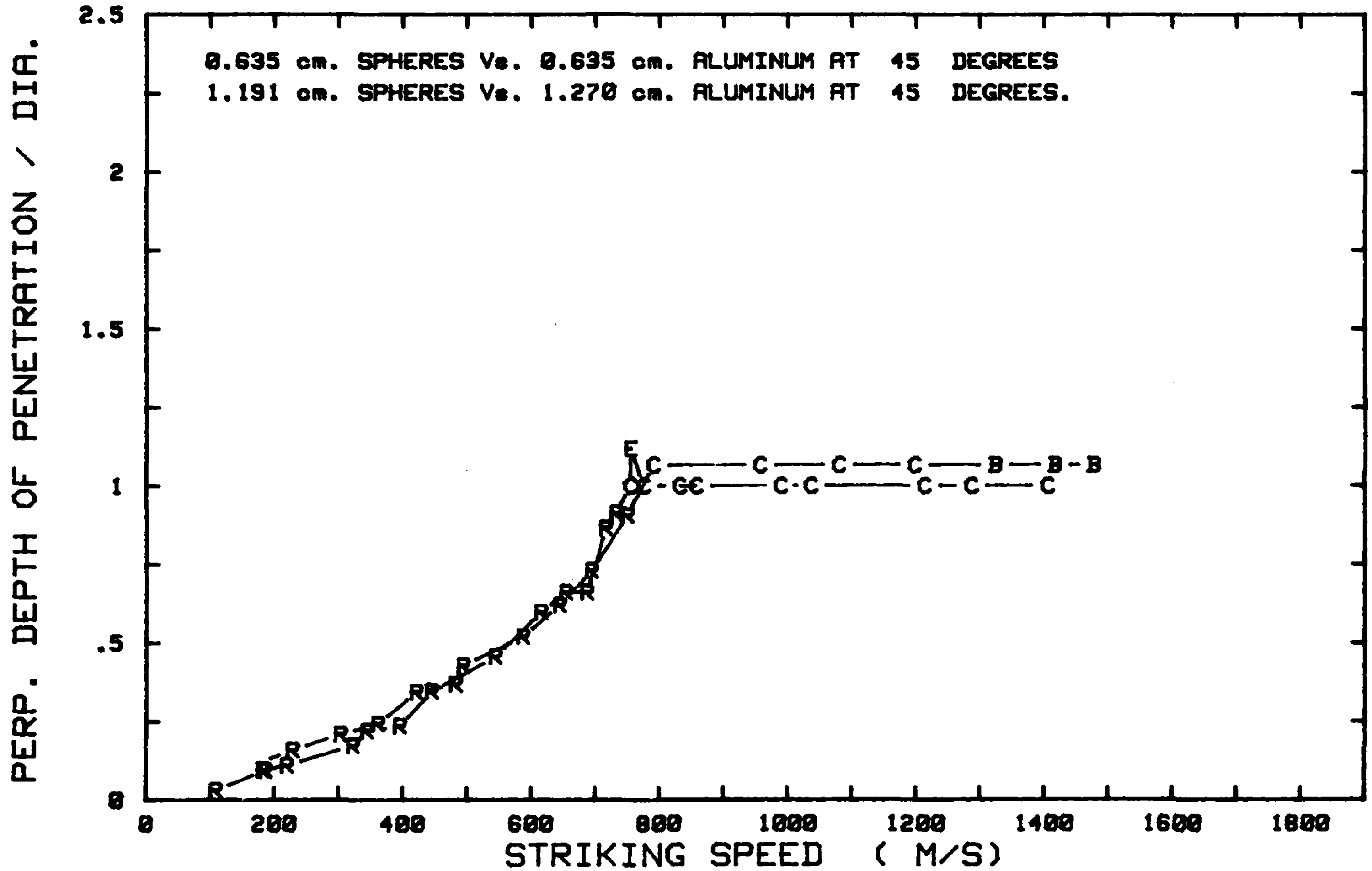


FIGURE 43 Ratio of Perp. Depth/Dia. Versus Striking Speed
For LOS/D = 1.414 or 1.508

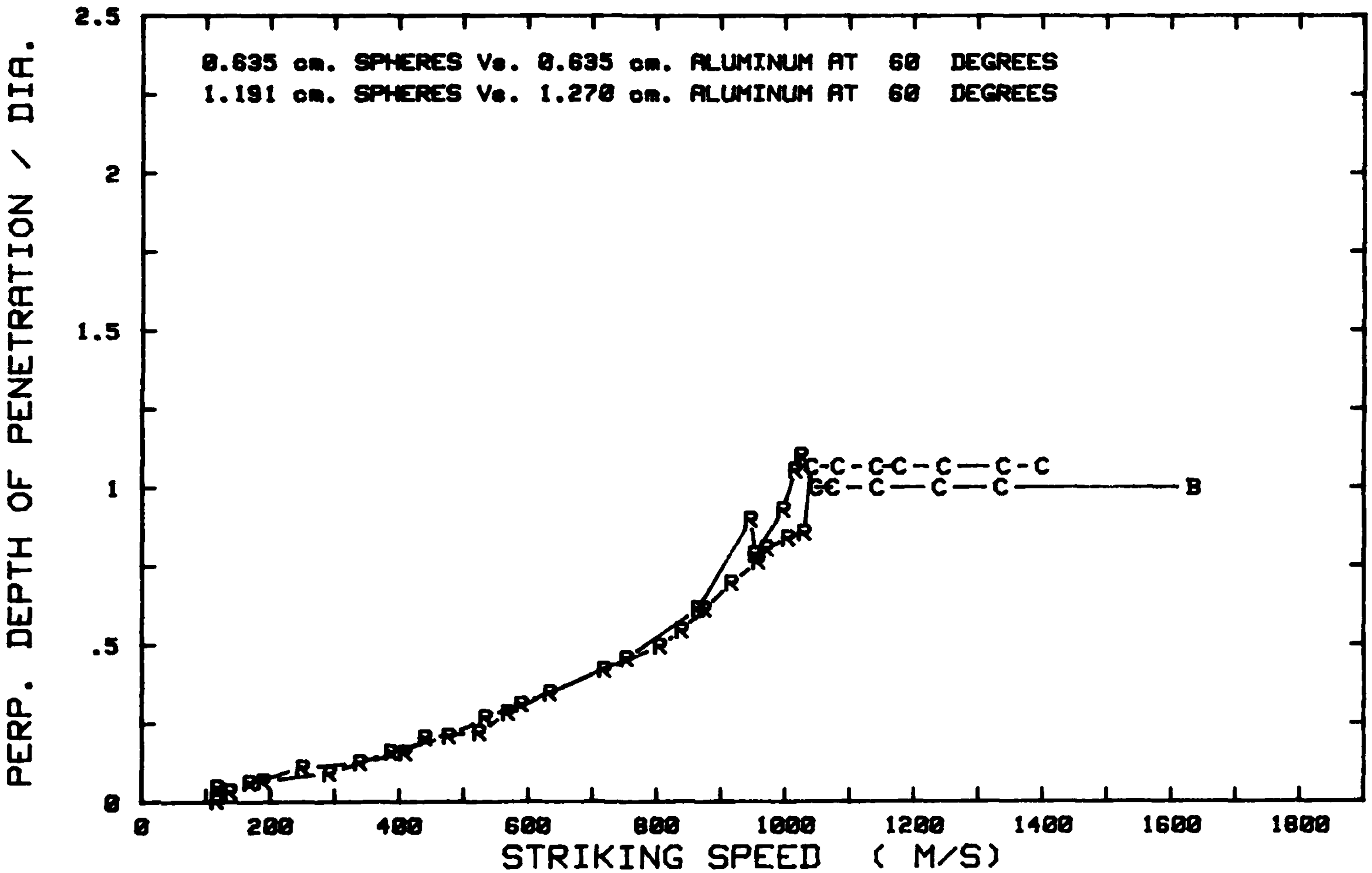


FIGURE 44 Ratio of Perp. Depth/Dia. Versus Striking Speed For LOS/D = 2.000 or 2.133

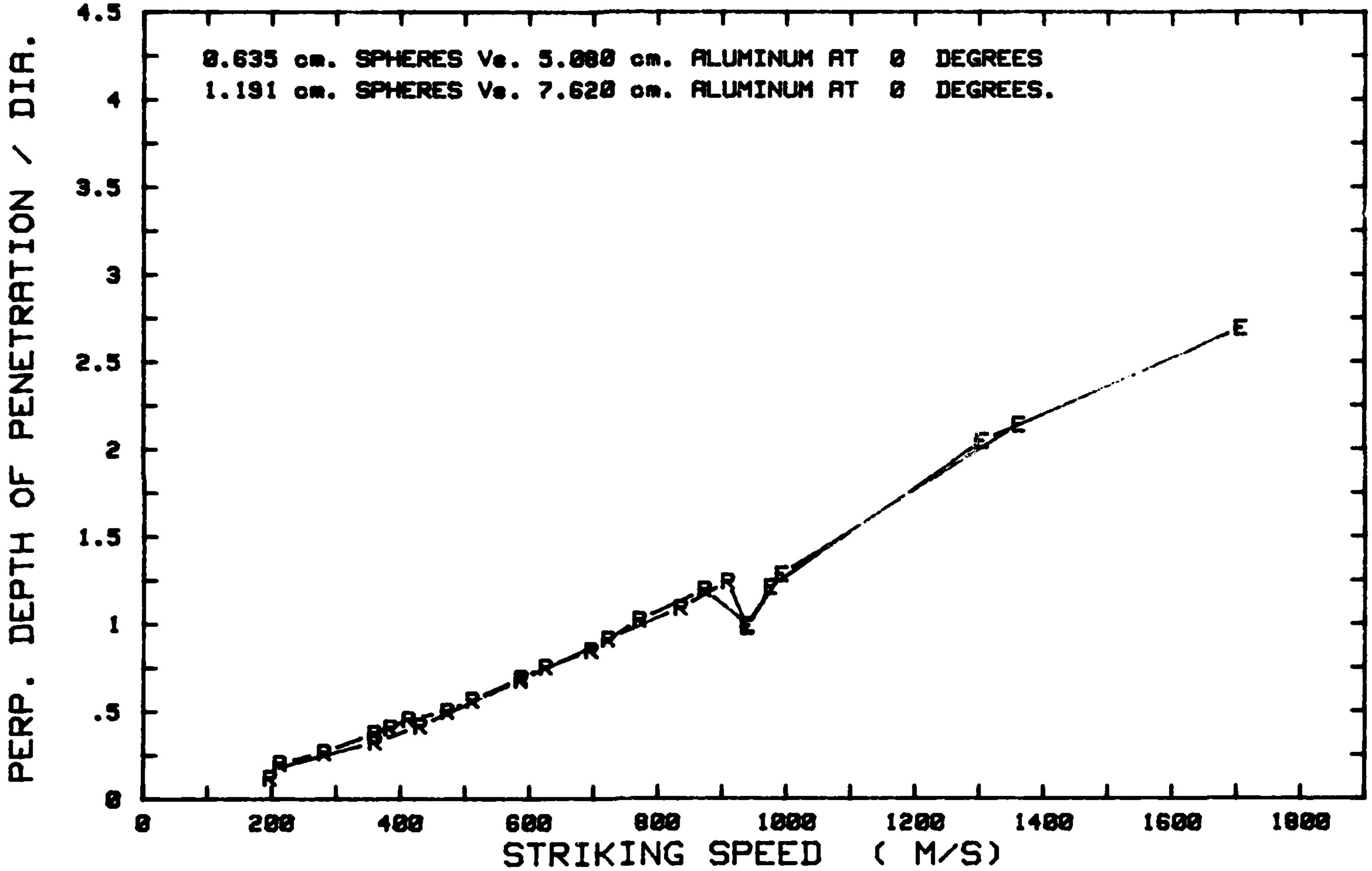


FIGURE 45 Ratio of Perp. Depth/Dia. Versus Striking Speed
For LOS/D = 'INF' at 0 deg.

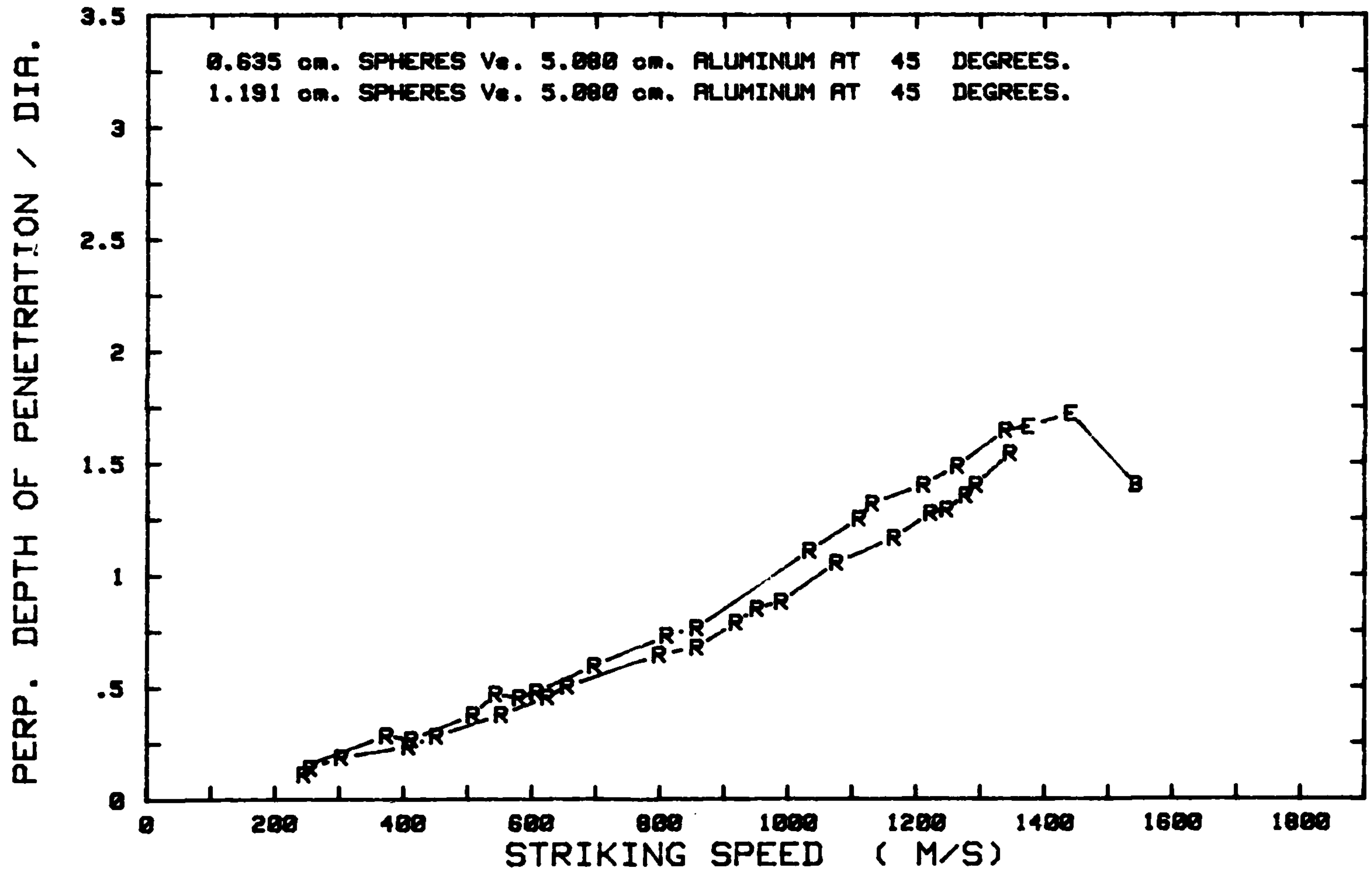


FIGURE 46 Ratio of Perp. Depth/Dia. Versus Striking Speed
For LOS/D = 'INF' at 45 degs.

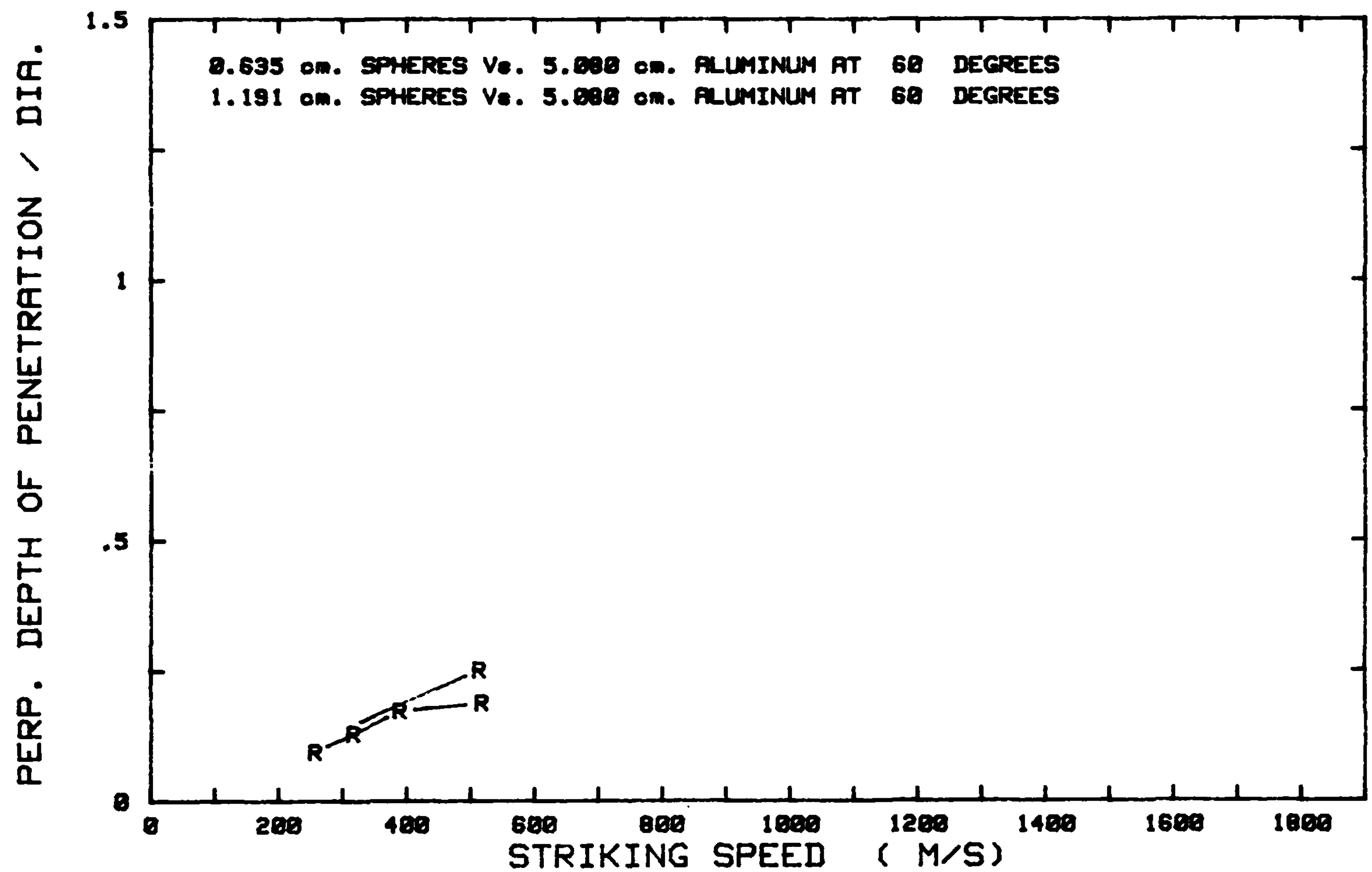


FIGURE 47 Ratio of Perp. Depth/Dia. Versus Striking Speed For LOS/D = 'INF' at 60 degs.

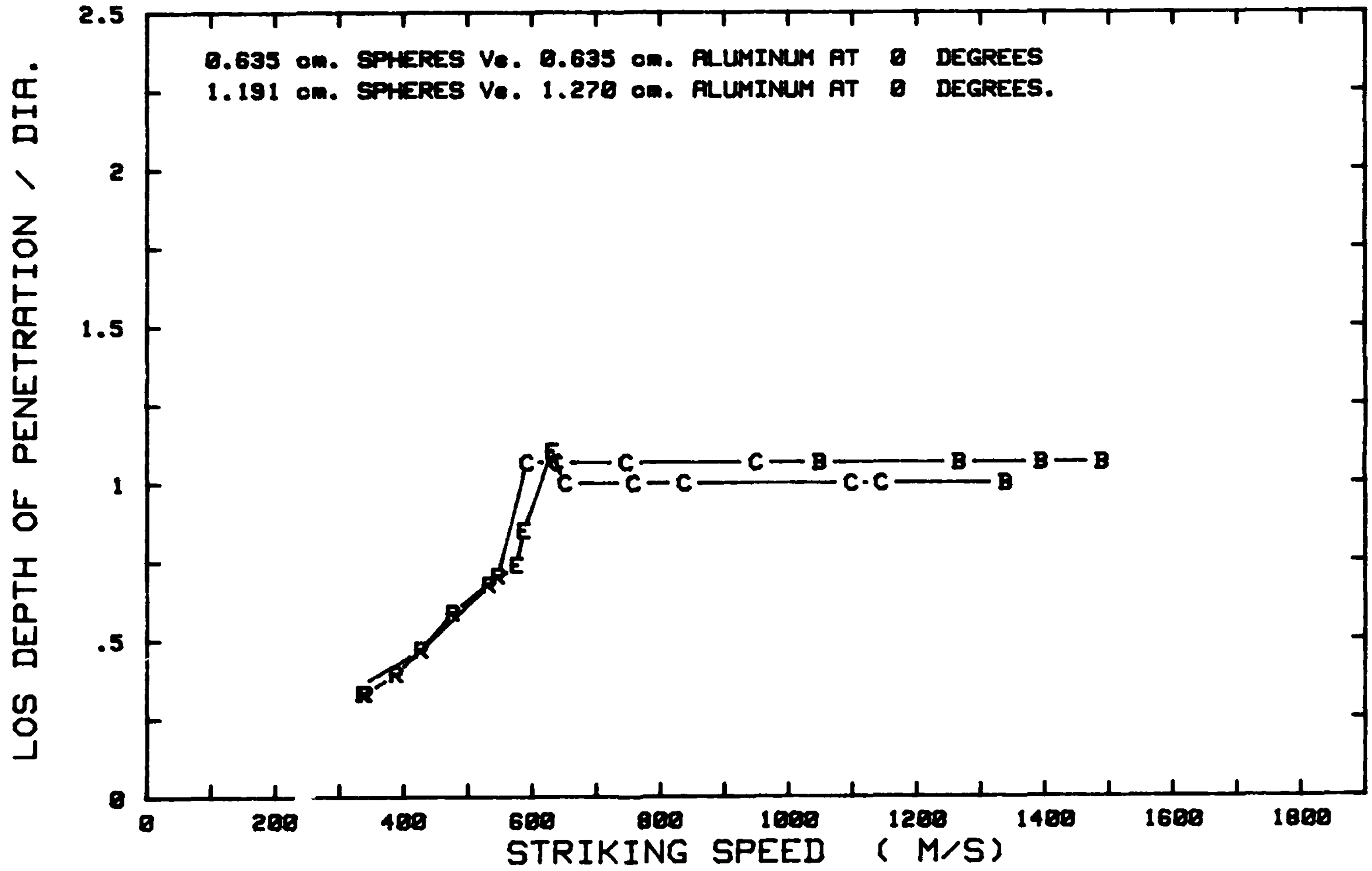


FIGURE 48 Ratio Of LOS Depth/Dia. Versus Striking Speed
For LOS/D = 1.000 or 1.067

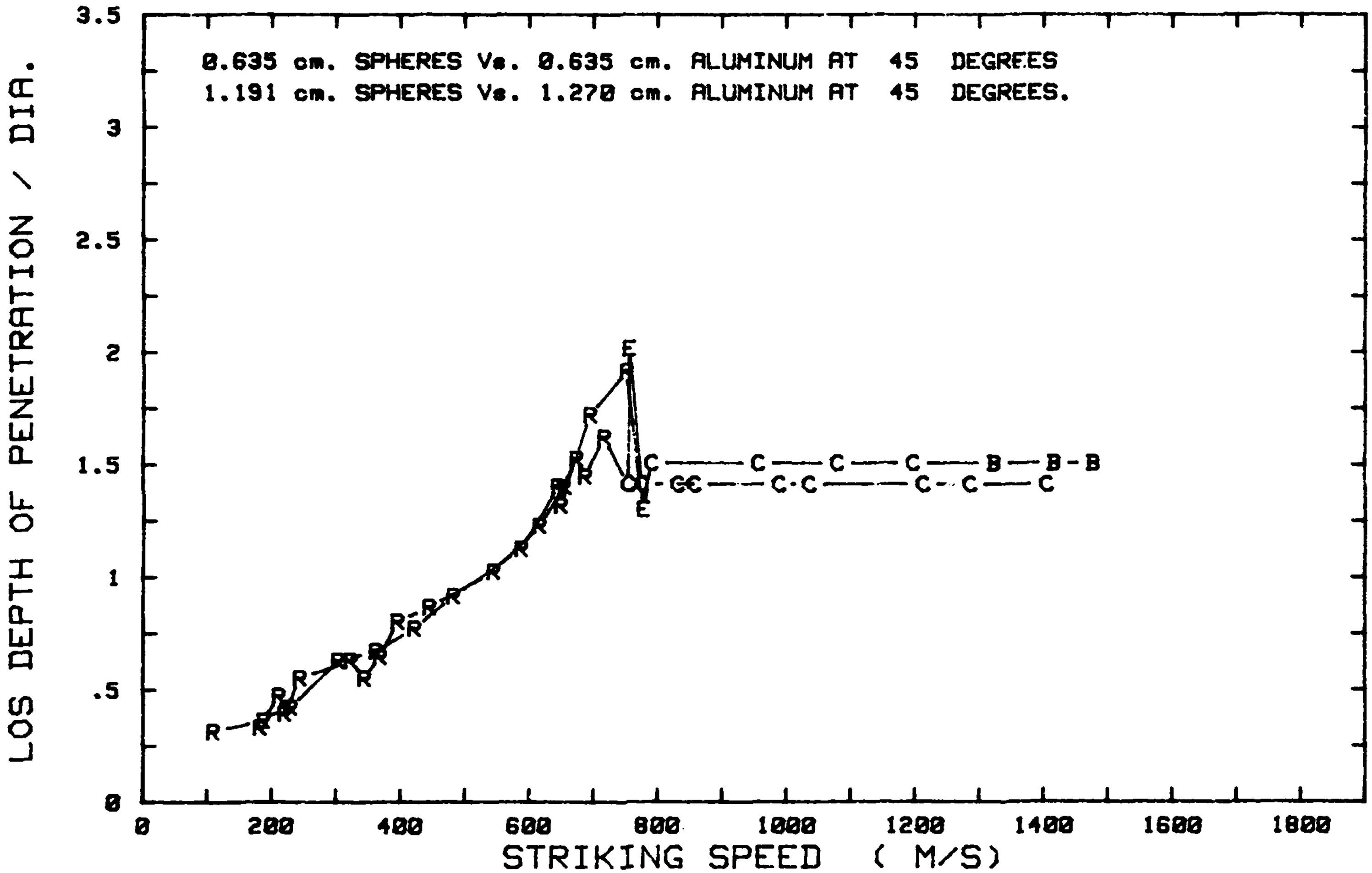


FIGURE 49 Ratio Of LOS Depth/Dia. Versus Striking Speed
For LOS/D = 1.414 or 1.508

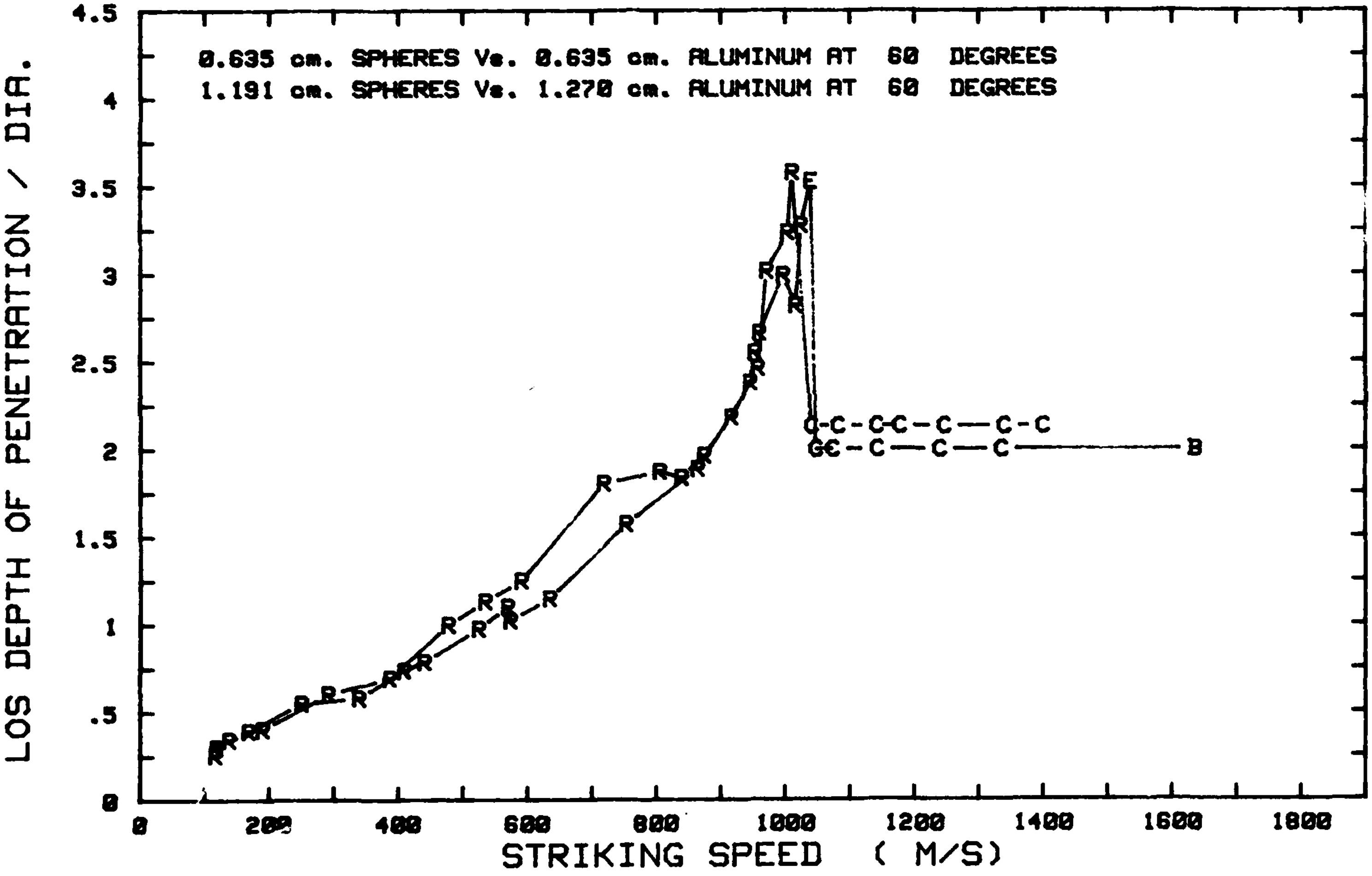


FIGURE 50 Ratio Of LOS Depth/Dia. Versus Striking Speed
For LOS/D = 2.000 or 2.133

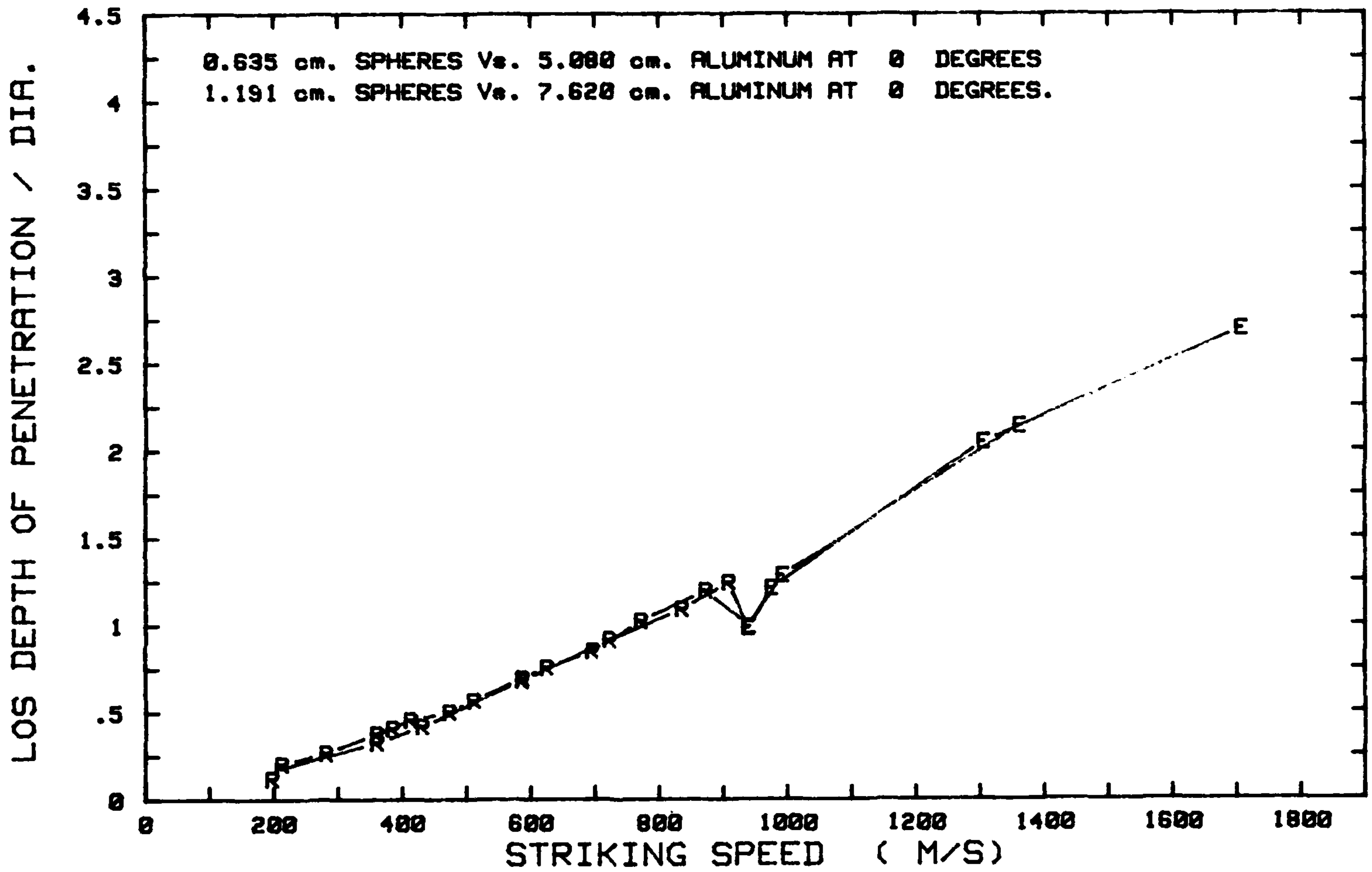


FIGURE 51 Ratio Of LOS Depth/Dia. Versus Striking Speed
For LOS/D = 'INF' at 0 deg.

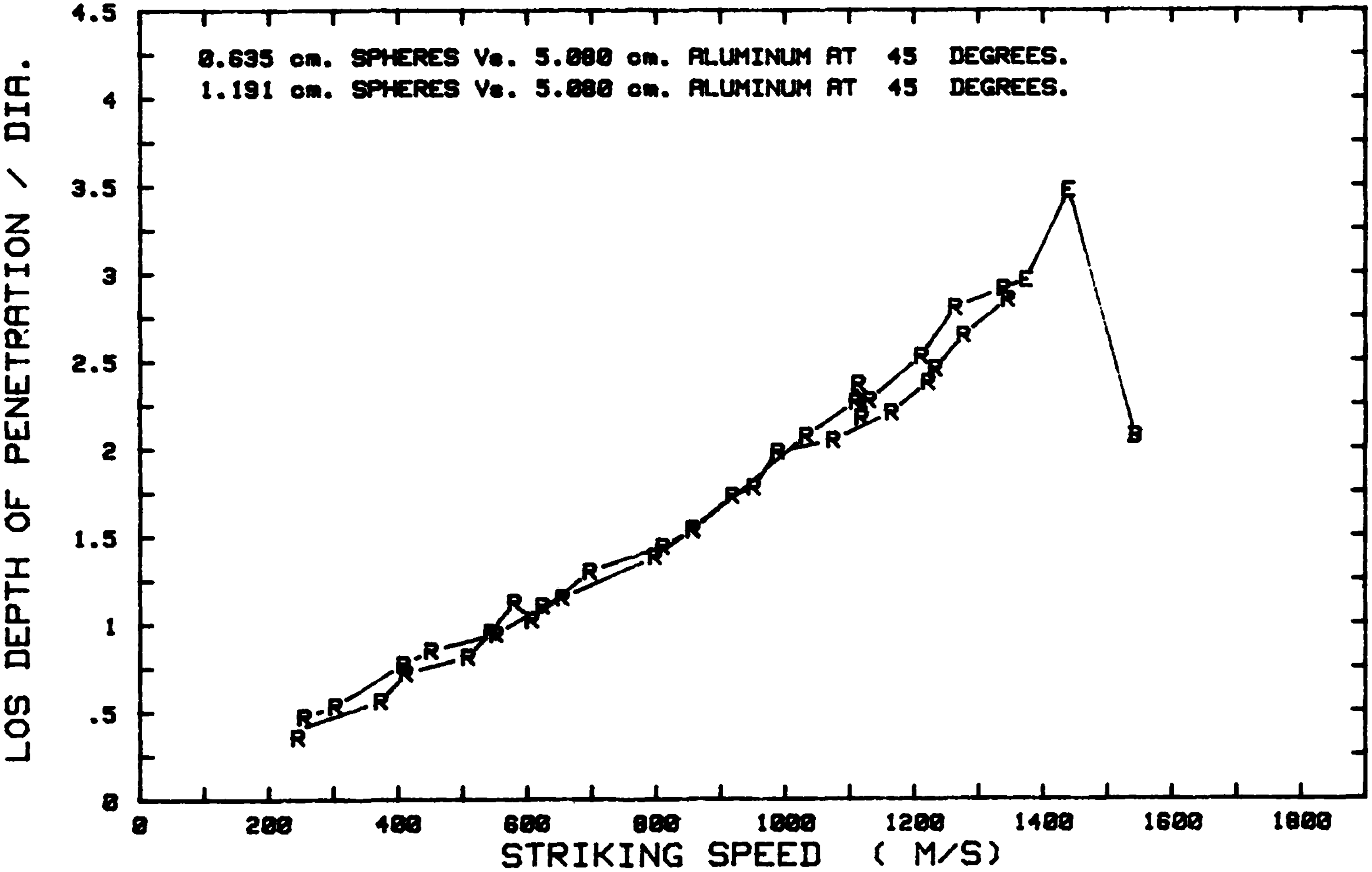


FIGURE 52 Ratio Of LOS Depth/Dia. Versus Striking Speed
For LOS/D = 'INF' at 45 degs.

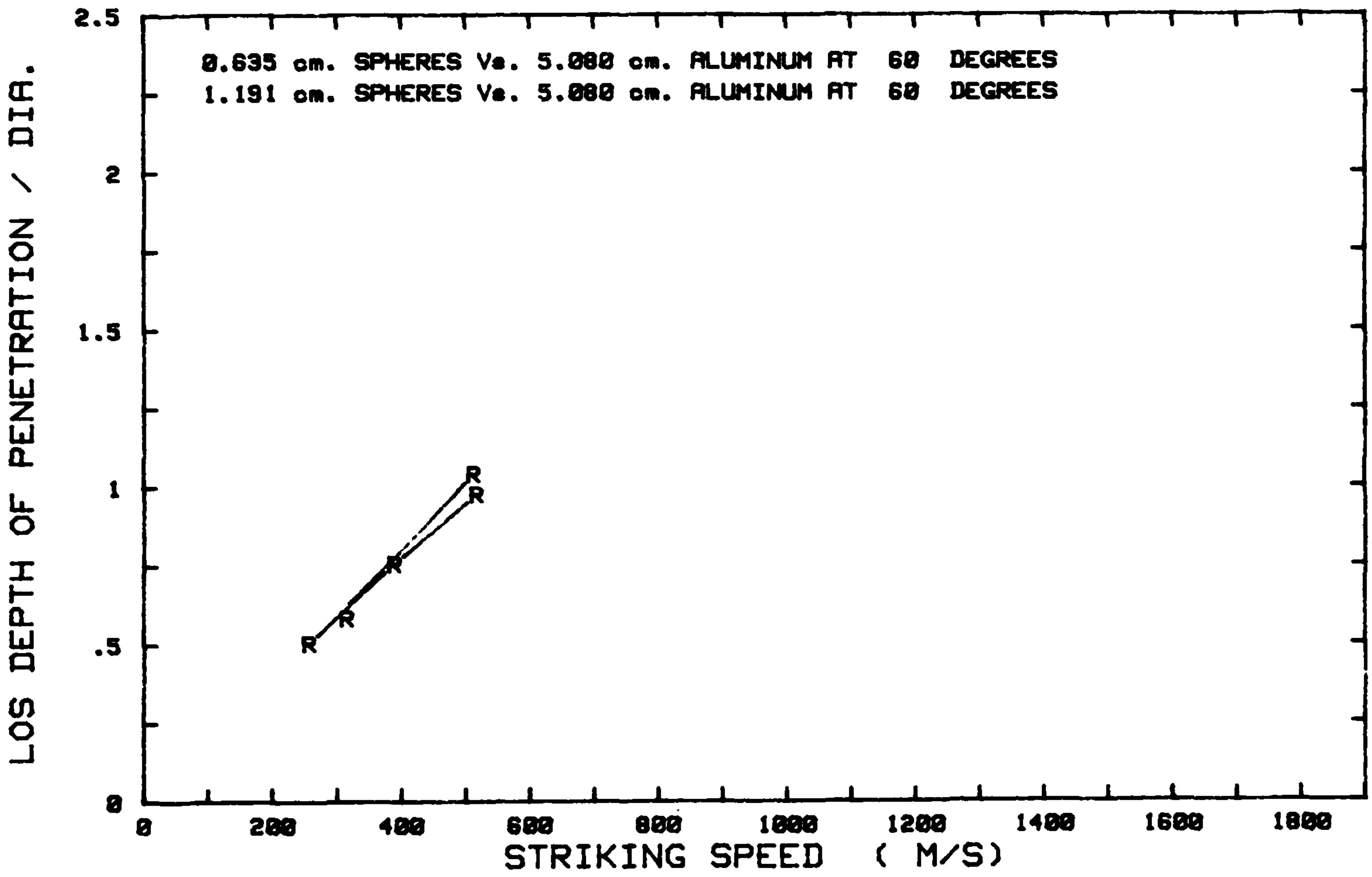


FIGURE 53 Ratio Of LOS Depth/Dia. Versus Striking Speed For LOS/D = 'INF' at 60 degs.

region. The values for these constants are $C_1 = 0.43$, $C_2 = 0.36$ and $C_3 = 0.13$.* The predictive curves shown in Figure 54 represent the data quite well and also for oblique impacts where the plate thickness is equated to the LOS thickness as shown in Figures 55 and 56.

III.3 A MODIFIED THOR EQUATION

A frequently used empirically derived equation for predicting residual speed (exit speed) as a function of the striking speed is the Thor equation.[3] The form of the equation is:

$$V_r = V_s - K\,(X_t A_p)^a\, M_p^c\, V_s^d\, (\mathrm{Sec}(\theta))^f \;, \qquad (4)$$

where K, a, c, d and f are constants.

The constants for the Thor equation were evaluated using a linear multiple regression least squares program. The values obtained using all of the sphere data are K = 9.117, a = 1.288, c = -1.309, d = -0.728 and f = 1.396. The curves resulting from using these constants in Equation 4 and the experimental sphere data are presented in Figure 58. As the comparison shows, the curve predictions fit the data well for the curves which pertain to the K, E and T symbol data but there is some deviation near the ballistic limit. However, the comparison for the curve related to the G symbol data is not good over the entire range of the data (not the same shape). The curves are more nearly straight lines while the data seem to follow parabolic shaped lines. Consequently, it was decided to modify Equation 4 as follows.

$$\tfrac{1}{2} M_p (V_s^2 - V_r^2) = K\, X_t^a\, A_p^b\, M_p^c\, V_s^d\, (\mathrm{Sec}(\theta))^f \;. \qquad (5)$$

The constants obtained, again using all of the sphere data, are K = 5.894, a = 0.877, b = 1.026, c = 0.0, d = 0.854 and f = 0.932. The curves using Equation 5 are compared to the data in Figure 59. By observation, it is clear that the comparison using Equation 5 is much better than the comparison of Figure 58 using Equation 4 especially near the ballistic limit.

The same analysis was conducted on the aluminum 2024-T3 plate data reported in Reference 3, where the penetrators were primarily right circular cylinders. The empirical constants for Equation 4 as reported in Reference 3

**The constants reported in Reference 1 are 0.70, 0.23 and 0.50 respectively and are based on right circular cylinder (rod) penetrators of length to diameter ratio (L/D) ranging from 0.61 to 0.96. Figure 57 is a plot showing the fit to one size of the rod penetrators.*

[3] *Project Thor, "The Resistance of Various Metallic Materials to Perforation by Steel Fragments: Empirical Relationships for Fragment Residual Velocity and Residual Weight," Technical Report Number 47, Ballistic Analysis Laboratory, Institute for Cooperative Research, The Johns Hopkins University, April 1961.*

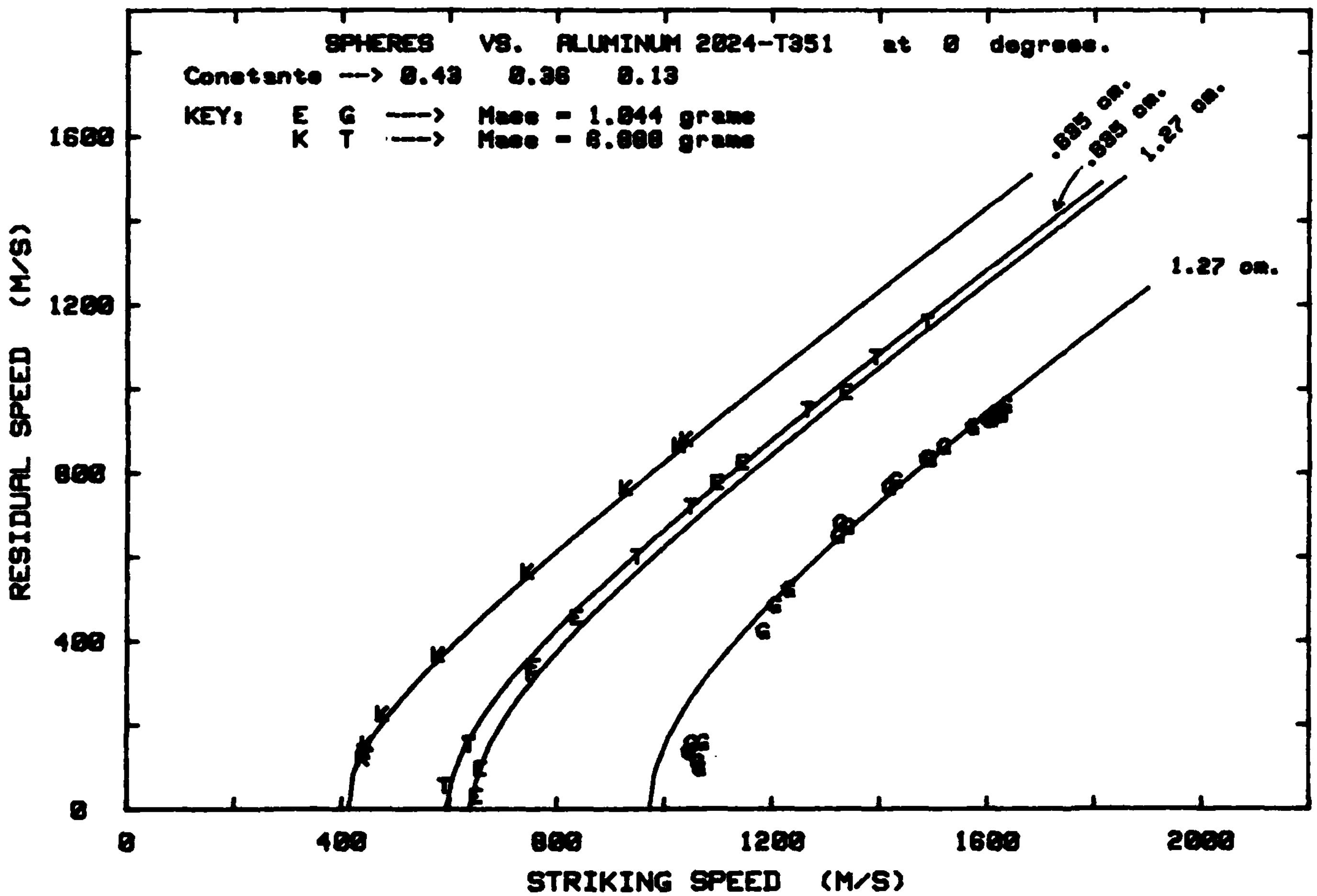


FIGURE 54 Comparison Of Sphere Experimental Data To Z/F Equation Predictions For Residual Speed Versus Striking Speed At 0 Deg.

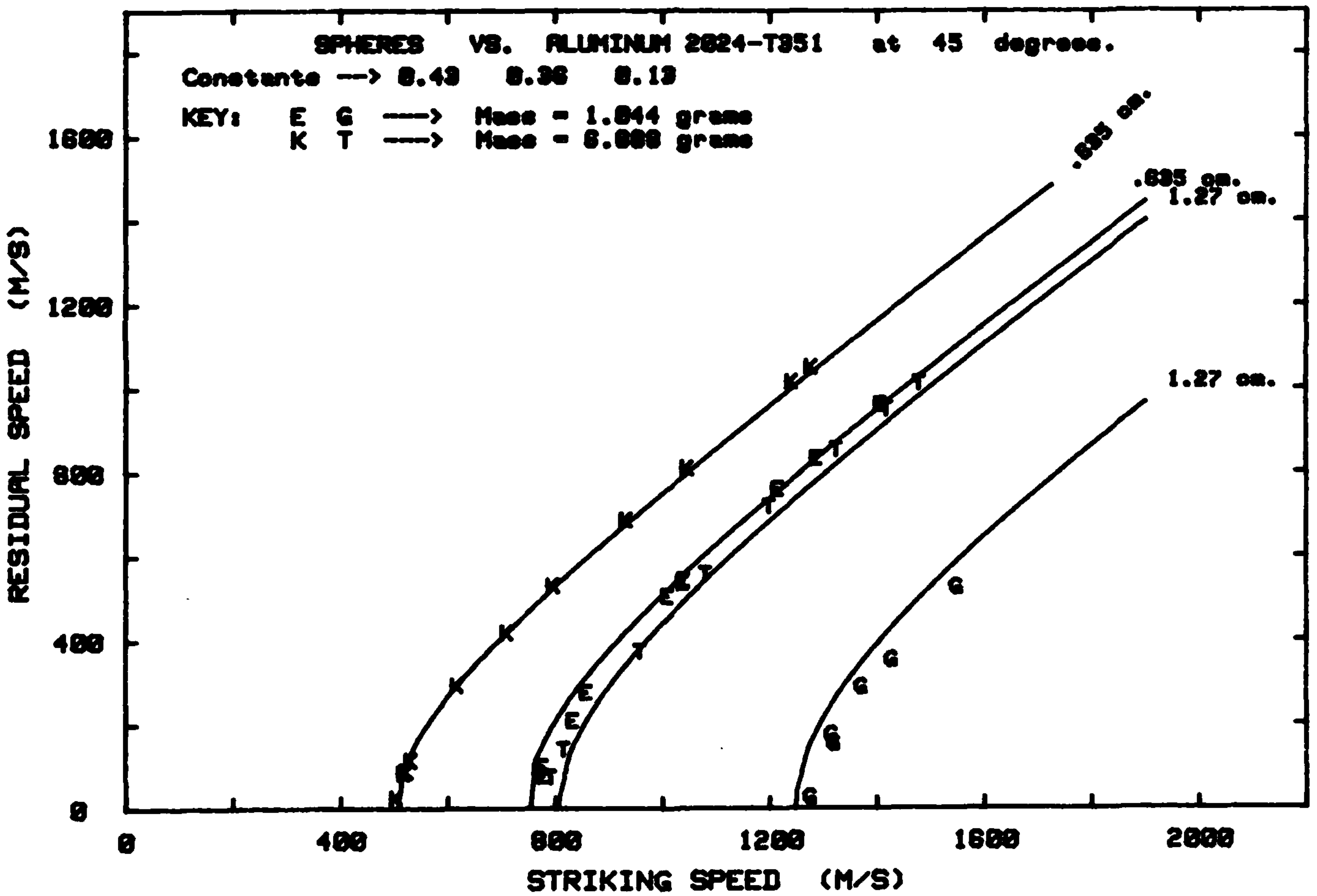


FIGURE 55 Comparison Of Sphere Experimental Data To Z/F Equation Predictions For Residual Speed Versus Striking Speed At 45 Deg.

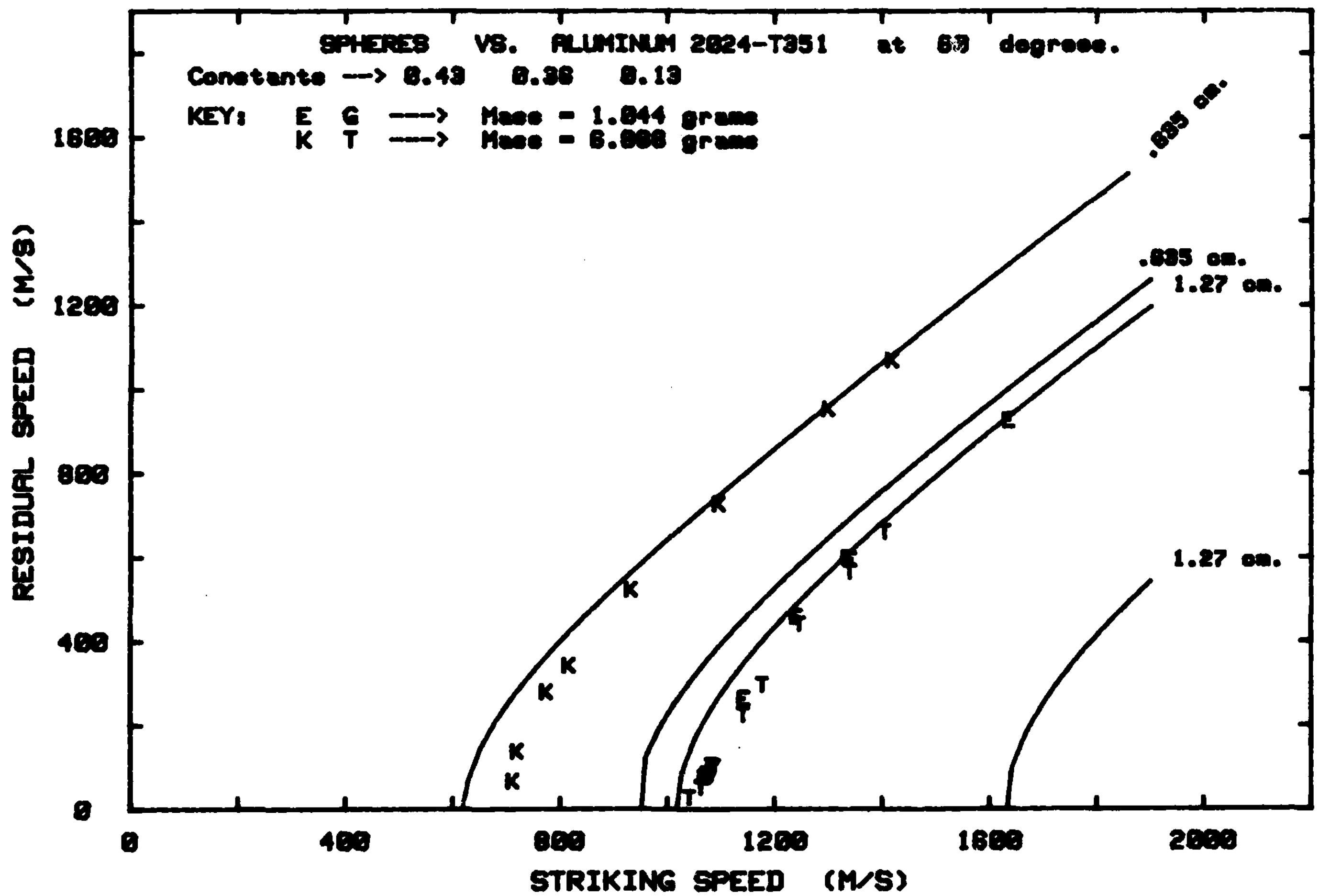


FIGURE 56 Comparison Of Sphere Experimental Data To Z/F Equation Predictions For Residual Speed Versus Striking Speed At 60 Deg.

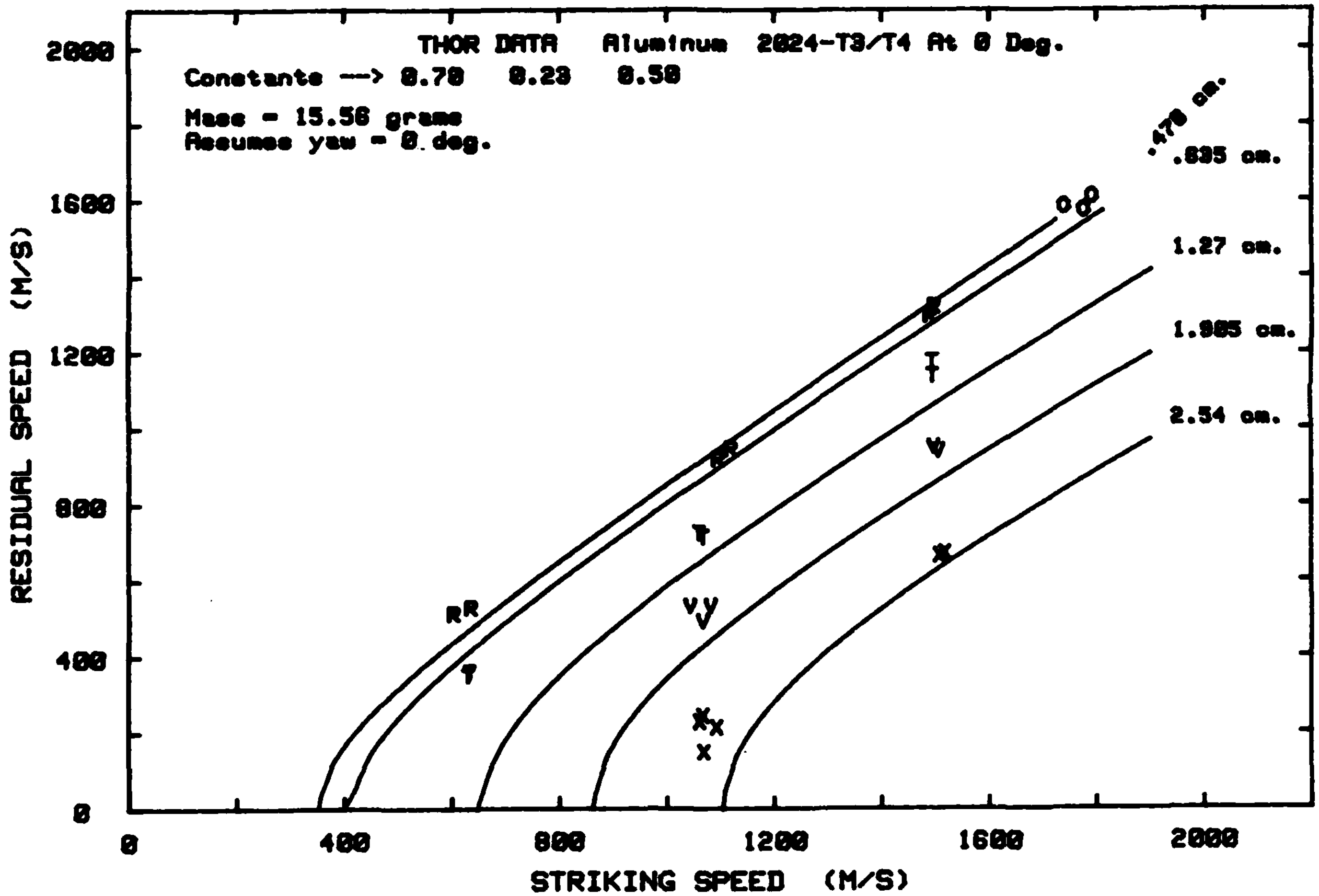


FIGURE 57 Comparison Of Rod Experimental Data To Z/F Equation Predictions For Residual Speed Versus Striking Speed At 0 Deg.

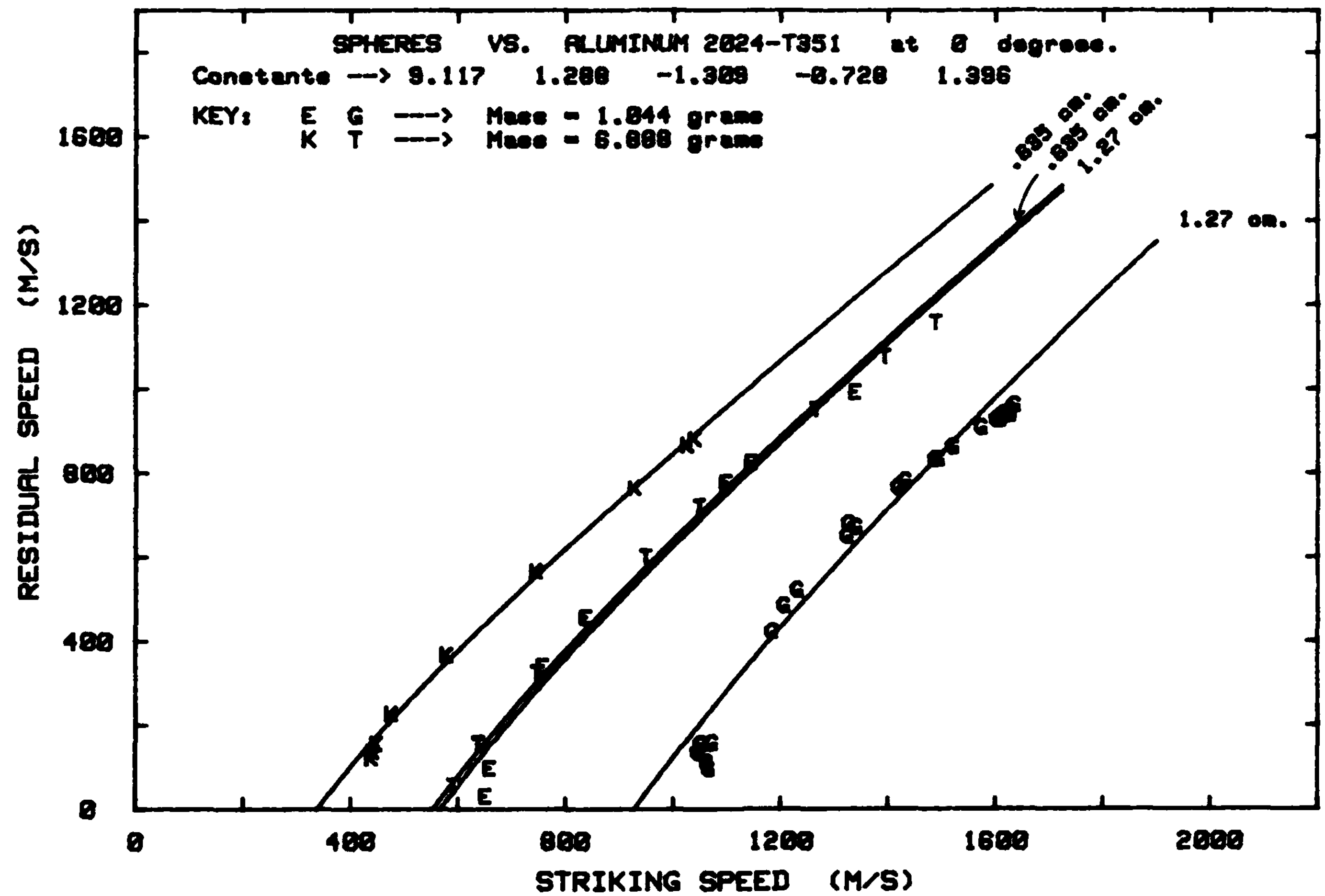


FIGURE 58 Comparison Of Sphere Experimental Data To Thor Equation Predictions For Residual Speed Versus Striking Speed At 0 Deg.

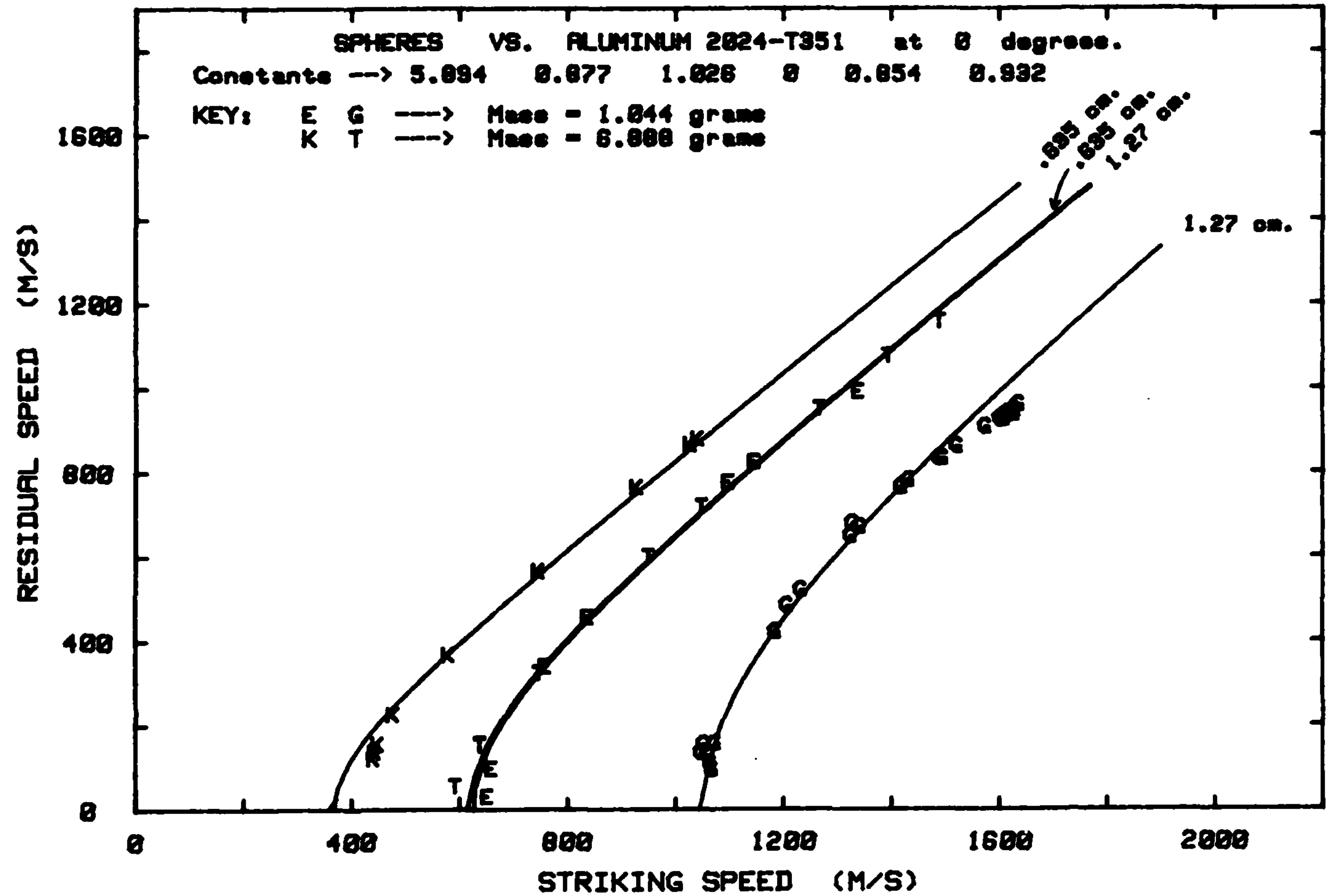


FIGURE 59 Comparison Of Sphere Experimental Data To Modified Thor Equation Predictions For Residual Speed Versus Striking Speed At 0 Deg.

are K = 6.214, a = 1.029, c = -1.072, d = -0.139 and f = 1.251 except that the value for K reflects a conversion of units from the British system to the metric system (CGS units). In attempting to reproduce these constants, the least squares program was used on the set of aluminum 2024-T3 data reported in Reference 3 excluding the data sets with a zero residual speed. This resulted in the values K = 3.426, a = 1.056, c = -1.052, d = 0.397 and f = 1.437. Even though these constants are slightly different from those of Reference 3, these are used in the following comparison since the exact procedure used in Reference 3 is not known. Figure 60 shows the comparison between the curves generated from Equation 4 using these constants and the experimental data for one size of the penetrators. This comparison indicates a rather unrealistic shape for the predicted curves in the neighborhood of the ballistic limit and entirely misses the data points in that region for the 2.54 cm thick plate. Evaluation of the constants for the modified Thor equation (Equation 5) using the same set of cylinder penetrator data resulted in K = 2.529, a = 0.835, b = 0.601, c = 0.305, d = 1.498, and f = 1.185. The predictions presented in Figure 61 show the improvement using Equation 5. Since the data are quite sparse, it is believed that the predictions would be even better if additional data were available (in particular, just above the ballistic limit) on which the constants could be evaluated.

IV. SUMMARY AND CONCLUSIONS

This study has provided a complete set of data for steel spheres impacting aluminum plates for two sphere sizes, three plate thicknesses, and three angles of obliquity. In those situations where the sphere is a good approximation of the impacting fragment, this set of data should be used. It has been shown that whenever the LOS/D is a constant for two or more cases, the resulting data will plot approximately on the same curve. Therefore, it is anticipated that the number of shots required for any future test series can be reduced significantly by utilizing that fact. Finally, the study has shown that the original Thor equation should be replaced by the modified version presented in this report.

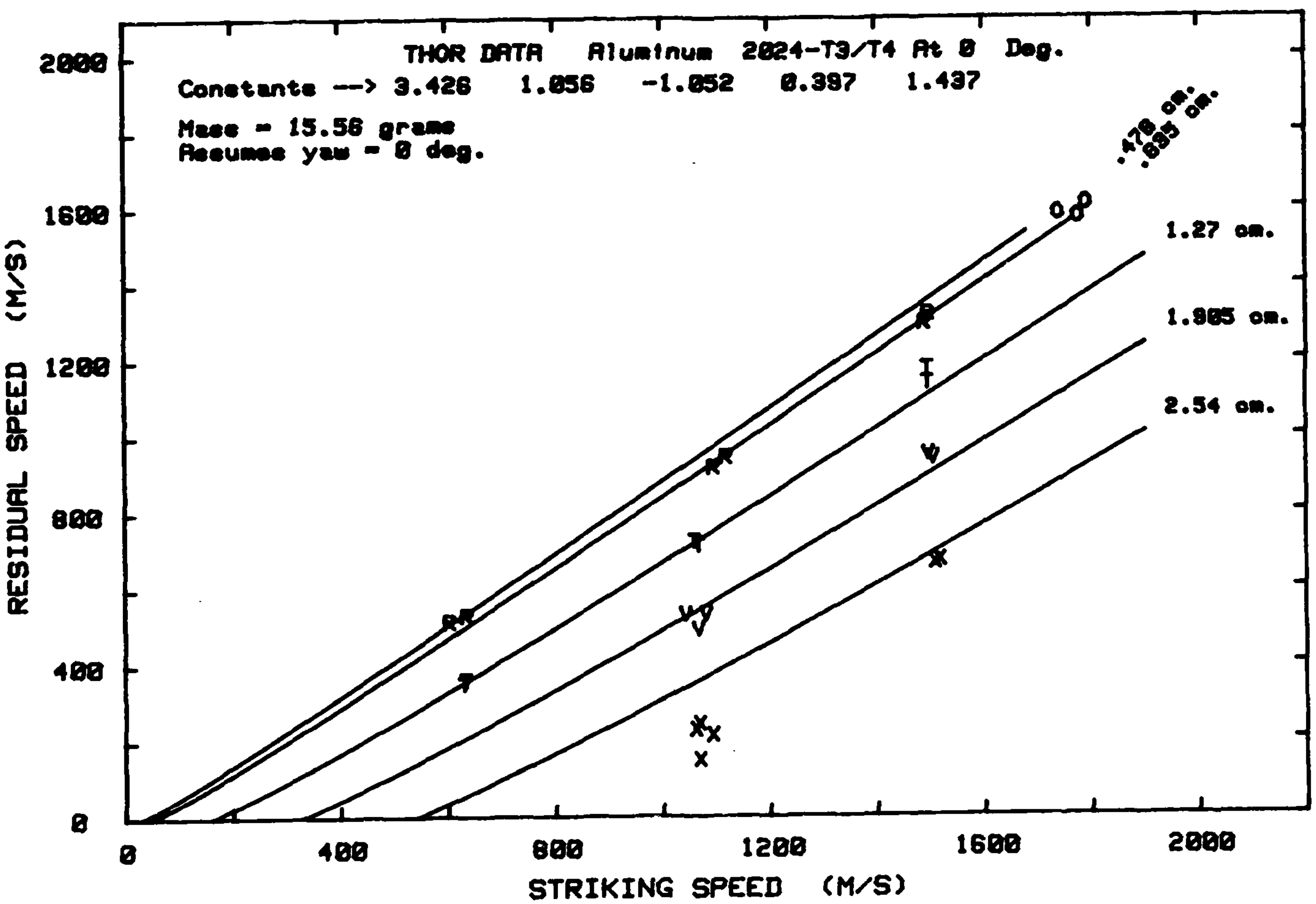


FIGURE 60 Comparison Of Rod Experimental Data To Thor Equation Predictions For Residual Speed Versus Striking Speed At 0 Deg.

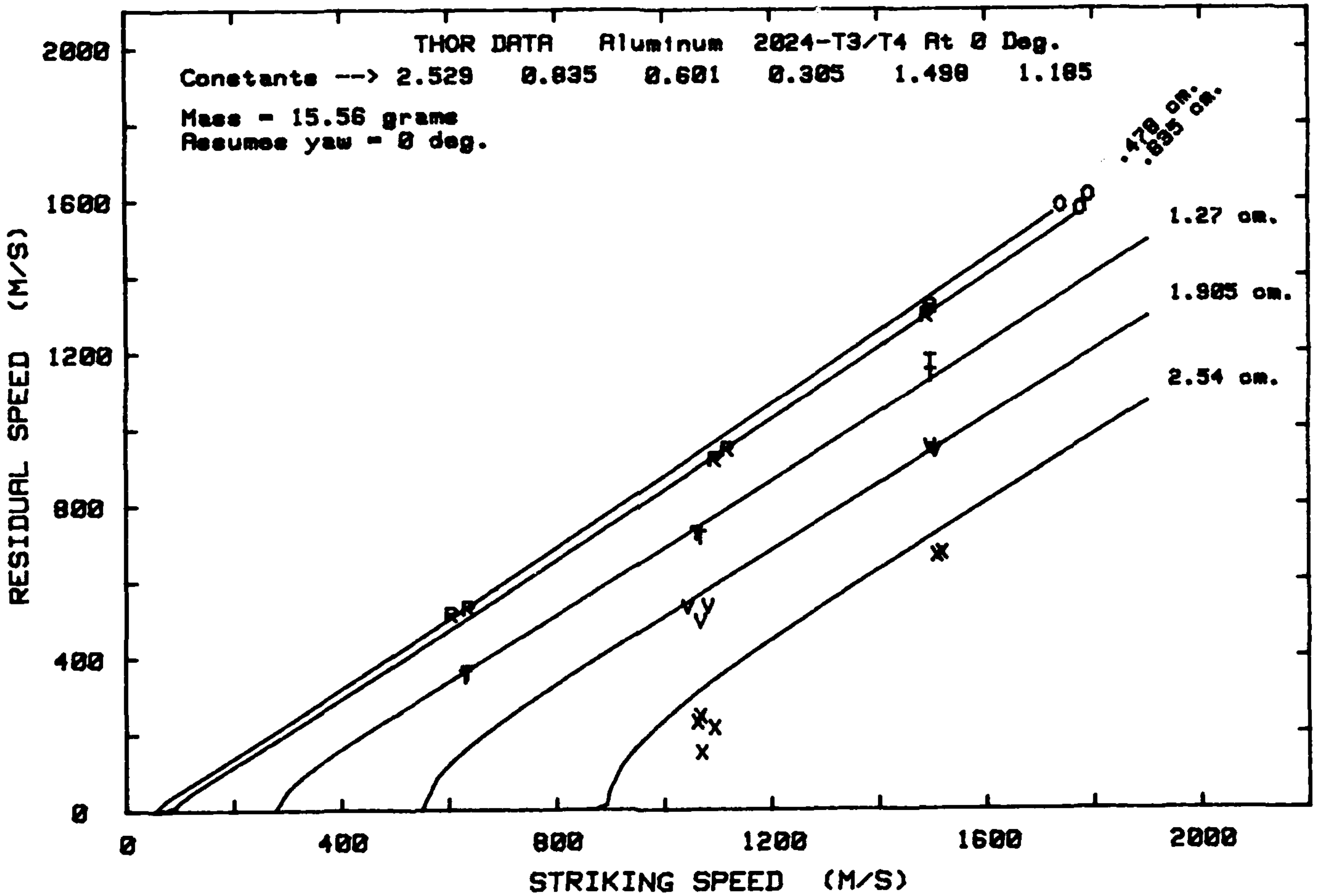


FIGURE 61 Comparison Of Rod Experimental Data To Modified Thor Equation Predictions For Residual Speed Versus Striking Speed At 0 Deg.

REFERENCES

1. John Zook, "An Analytical Model of Kinetic Energy Projectile/Fragment Penetration," BRL MR 2797, October 1977.

2. James Dehn, "The Particle Dynamics of Target Penetration," ARBRL TR 02188, September 1979 (ADA 077114).

3. Project Thor, "The Resistance of Various Metallic Materials to Perforation by Steel Fragments: Empirical Relationships for Fragment Residual Velocity and Residual Weight," Technical Report Number 47, Ballistics Analysis Laboratory, Institute For Cooperative Research, The Johns Hopkins University, April 1961.

APPENDIX A

TABULATED EXPERIMENTAL DATA VALUES

LIST OF TABLES

LIST OF TABLES (continued)

TABLE A1a. Target Effects Data For 1/4 Inch Spheres Impacting 1/4 Inch Aluminum At 0 Degrees

PENETRATOR CHARACTERISTICS		TARGET CHARACTERISTICS	
SHAPE	- Sphere (Ball Bearing)	SHAPE	- (7.6 or 10) x 30 cm. Plate
MATERIAL	- Steel	MATERIAL	- Aluminum 2024-T351
DIAMETER	- 0.635 cm.	THICKNESS	- 0.635 cm.
MASS	- 1.044 g.	HARDNESS	- 143 BHN
HARDNESS	- 65 Rc	IMPACT ANGLE	- 0°

	STRIKING SPEED (m/s)	EXIT SPEED (m/s)	EXIT ANGLE (deg)	LOS PENETRATION (cm)	PERPENDICULAR PENETRATION (cm)	RECOVERED PENETRATOR MIN. DIA (cm)	RECOVERED PENETRATOR MAX. DIA (cm)	RECOVERED PENETRATOR MASS (g)	SHOT IDENTIFICATION
1	341	5	171.0	0.21	0.21	N/A	N/A	N/A	FP-1-81-06-18-4
2	388	6	179.7	0.25	0.25	0.634	0.634	1.044	FP-1-81-06-18-3
3	533	N/A	N/A	0.43	0.43	0.634	0.636	1.045	FP-1-82-01-22-1
4	537	N/A	N/A	0.45	0.45	0.634	0.634	1.044	FP-1-81-06-18-2
5	576	0	*	0.47	0.47	N/A	N/A	N/A	FP-1-81-06-18-1
6	587	0	*	0.54	0.54	N/A	N/A	N/A	FP-1-81-01-27-1
7	631	0	*	0.70	0.70	N/A	N/A	N/A	FP-1-82-01-28-1
8	650	32	0.5	C/P	C/P	N/A	N/A	N/A	FP-1-82-01-21-1
9	658	98	5.2	C/P	C/P	0.632	0.636	1.044	FP-1-82-01-29-1
10	757	340	0.3	C/P	C/P	0.629	0.637	1.044	FP-1-82-01-20-1
11	836	457	0.1	C/P	C/P	0.630	0.637	1.046	FP-1-82-01-19-1
12	1097	777	0.2	C/P	C/P	0.620	0.645	1.046	FP-1-82-01-18-1
13	1144	825	0.3	C/P	C/P	0.620	0.646	1.047	FP-1-82-01-15-2
14	1338	992	0.5	C/P	C/P	*	*	**	FP-1-82-01-15-1

C/P - Complete penetration N/A - Not available * - Not applicable
** - Penetrator broke up; see last table of this Appendix
Note: Exit angles greater than 90° are ricochet angles.

TABLE A1b. Target Effects Data For 1/4 Inch Spheres Impacting 1/4 Inch Aluminum At 0 Degrees

PENETRATOR CHARACTERISTICS

SHAPE	- Sphere (Ball Bearing)
MATERIAL	- Steel
DIAMETER	- 0.635 cm.
MASS	- 1.044 g.
HARDNESS	- 65 Rc

TARGET CHARACTERISTICS

SHAPE	- (7.6 or 10) x 30 cm. Plate
MATERIAL	- Aluminum 2024-T351
THICKNESS	- 0.635 cm.
HARDNESS	- 143 BHN
IMPACT ANGLE	- 0°

	HOLE DIAMETERS ENTRANCE Min. (cm)	HOLE DIAMETERS ENTRANCE Max. (cm)	HOLE DIAMETERS EXIT Min. (cm)	HOLE DIAMETERS EXIT Max. (cm)	CRATER WIDTH (cm)	CRATER LENGTH (cm)	GROOVE WIDTH (cm)	GROOVE LENGTH (cm)	REAR SURFACE BULGE (cm)	SHOT IDENTIFICATION
1	0.60	0.60	0.60	0.60	F 0.60	F 0.60	*	*	0.07	FP-1-81-06-18-4
2	0.60	0.60	0.60	0.60	F 0.63	F 0.78	*	*	0.07	FP-1-81-06-18-3
3	0.68	0.68	0.68	0.68	F 0.68	F 0.68	*	*	0.16	FP-1-82-01-22-1
4	0.60	0.60	0.60	0.60	F 0.78	F 0.78	*	*	0.17	FP-1-81-06-18-2
5	0.61	0.61	*	*	F 0.73	F 0.78	*	*	0.20	FP-1-81-06-18-1
6	0.61	0.61	*	*	F 0.69	F 0.69	*	*	0.22	FP-1-82-01-27-1
7	0.61	0.61	*	*	F 0.70	F 0.70	*	*	0.30	FP-1-82-01-28-1
					R 0.53	R 0.58				
8	0.58	0.58	0.58	0.58	F 0.78	F 0.78	*	*	*	FP-1-82-01-21-1
					R 0.83	R 1.00				
9	0.59	0.59	0.59	0.59	F 0.76	F 0.90	*	*	*	FP-1-82-01-29-1
					R 0.88	R 1.00				
10	0.58	0.58	0.58	0.58	F 0.80	F 0.80	*	*	*	FP-1-82-01-20-1
					R 1.00	R 1.00				
11	0.59	0.59	0.59	0.59	F 0.87	F 0.87	*	*	*	FP-1-82-01-19-1
					R 1.00	R 1.00				
12	0.59	0.59	0.59	0.59	F 0.90	F 0.90	*	*	*	FP-1-82-01-18-1
					R 1.00	R 1.00				

F - the entrance side of the target plate; R - the exit side of the target plate
N/A - Not available * - Not applicable

TABLE A1b. (Continued)

	HOLE DIAMETERS ENTRANCE Min. (cm)	HOLE DIAMETERS ENTRANCE Max. (cm)	HOLE DIAMETERS EXIT Min. (cm)	HOLE DIAMETERS EXIT Max. (cm)	CRATER WIDTH (cm)	CRATER LENGTH (cm)	GROOVE WIDTH (cm)	GROOVE LENGTH (cm)	REAR SURFACE BULGE (cm)	SHOT IDENTIFICATION
13	0.60	0.60	0.60	0.60	F 0.91 R 1.09	F 0.91 R 1.09	*	*	*	FP-1-82-01-15-2
14	0.66	0.66	0.66	0.66	F 0.93 R 1.14	F 0.93 R 1.19	*	*	*	FP-1-82-01-15-1

F - the entrance side of the target plate; R - the exit side of the target plate
N/A - Not available * - Not applicable

TABLE A2a. Target Effects Data For 1/4 Inch Spheres Impacting 1/2 Inch Aluminum At 0 Degrees

PENETRATOR CHARACTERISTICS		TARGET CHARACTERISTICS	
SHAPE	- Sphere (Ball Bearing)	SHAPE	- (7.6 or 10) x 30 cm. Plate
MATERIAL	- Steel	MATERIAL	- Aluminum 2024-T351
DIAMETER	- 0.635 cm.	THICKNESS	- 5.080 cm.
MASS	- 1.044 g.	HARDNESS	- 153 BHN
HARDNESS	- 65 Rc	IMPACT ANGLE	- 0°

	STRIKING SPEED (m/s)	EXIT SPEED (m/s)	EXIT ANGLE (deg)	LOS PENETRATION (cm)	PERPENDICULAR PENETRATION (cm)	RECOVERED PENETRATOR MIN. DIA (cm)	RECOVERED PENETRATOR MAX. DIA (cm)	RECOVERED PENETRATOR MASS (g)	SHOT IDENTIFICATION
1	206	36	178.8	0.14	0.14	N/A	N/A	N/A	FP-1-81-06-11-2
2	214	38	178.6	0.14	0.14	0.634	0.634	1.044	FP-1-81-06-10-2
3	225	37	179.5	0.15	0.15	0.634	0.634	1.043	FP-1-81-06-11-4
4	228	37	179.8	0.16	0.16	N/A	N/A	N/A	FP-1-81-06-09-1
5	264	40	179.4	0.19	0.19	N/A	N/A	N/A	FP-1-81-06-10-3
6	272	40	180.0	0.21	0.21	0.634	0.634	1.043	FP-1-81-06-10-1
7	434	46	181.0	0.24	0.24	0.634	0.634	1.044	FP-1-81-06-11-3
8	437	N/A	N/A	0.31	0.31	0.635	0.635	1.044	FP-1-81-06-08-1
9	469	47	181.0	0.30	0.30	0.634	0.635	1.044	FP-1-81-06-08-2
10	536	45	179.5	0.36	0.36	0.634	0.635	1.044	FP-1-81-06-11-1
11	635	16	179.6	0.48	0.48	N/A	N/A	N/A	FP-1-81-06-10-5
12	956	0.00	*	1.1	1.1	N/A	N/A	N/A	FP-1-81-06-03-2
13	967	0.00	*	1.02	1.02	N/A	N/A	N/A	FP-1-78-08-09-1
14	993	0.00	*	1.12	1.12	N/A	N/A	N/A	FP-1-78-08-02-1
15	1003	0.00	*	1.13	1.13	N/A	N/A	N/A	FP-1-78-08-03-1
16	1009	0.00	*	1.17	1.17	N/A	N/A	N/A	FP-1-78-08-10-1
17	1016	0.00	*	1.15	1.15	N/A	N/A	N/A	FP-1-78-08-02-2
18	1020	0.00	*	1.31	1.31	N/A	N/A	N/A	FP-1-78-08-11-3
19	1031	0.00	*	1.34	1.34	N/A	N/A	N/A	FP-1-78-08-10-2
20	1032	0.00	*	1.54	1.54	N/A	N/A	N/A	FP-1-78-08-09-2

C/P - Complete penetration N/A - Not available * - Not applicable
** - Penetrator broke up; see last table of this Appendix
Note: Exit angles greater than 90° are ricochet angles.

TABLE A2a. (Continued)

	STRIKING SPEED (m/s)	EXIT SPEED (m/s)	EXIT ANGLE (deg)	LOS PENETRATION (cm)	PERPENDICULAR PENETRATION (cm)	RECOVERED PENETRATOR MIN. DIA (cm)	RECOVERED PENETRATOR MAX. DIA (cm)	RECOVERED PENETRATOR MASS (g)	SHOT IDENTIFICATION
21	1038	N/A	N/A	C/P	C/P	N/A	N/A	N/A	FP-1-78-08-03-4
22	1045	137	-1.4	C/P	C/P	0.623	0.640	1.045	FP-1-81-06-03-3
23	1050	157	0.4	C/P	C/P	N/A	N/A	N/A	FP-1-78-08-11-2
24	1052	N/A	N/A	C/P	C/P	N/A	N/A	N/A	FP-1-78-08-03-2
25	1062	112	-0.1	C/P	C/P	N/A	N/A	N/A	FP-1-78-08-11-1
26	1065	97	0.4	C/P	C/P	N/A	N/A	N/A	FP-1-78-08-10-3
27	1071	159	3.6	C/P	C/P	0.621	0.638	1.044	FP-1-81-06-04-3
28	1072	N/A	N/A	C/P	C/P	N/A	N/A	N/A	FP-1-78-08-03-3
29	1183	423	-0.4	C/P	C/P	N/A	N/A	N/A	FP-1-81-06-04-1
30	1205	485	-0.2	C/P	C/P	0.616	0.639	1.044	FP-1-79-01-22-1
31	1230	522	0.7	C/P	C/P	N/A	N/A	N/A	FP-1-79-01-22-2
32	1301	N/A	N/A	C/P	C/P	N/A	N/A	N/A	FP-1-81-06-02-1
33	1323	651	0.5	C/P	C/P	N/A	N/A	N/A	FP-1-79-01-19-4
34	1326	681	0.8	C/P	C/P	0.611	0.643	1.044	FP-1-81-06-03-1
35	1340	672	0.5	C/P	C/P	N/A	N/A	N/A	FP-1-79-01-19-5
36	1417	766	0.3	C/P	C/P	N/A	N/A	N/A	FP-1-79-01-19-3
37	1430	782	0.2	C/P	C/P	N/A	N/A	N/A	FP-1-79-01-19-2
38	1486	834	0.5	C/P	C/P	N/A	N/A	N/A	FP-1-79-01-18-5
39	1492	834	0.4	C/P	C/P	N/A	N/A	N/A	FP-1-78-08-08-1
40	1519	863	0.7	C/P	C/P	N/A	N/A	N/A	FP-1-79-01-19-1

C/P - Complete penetration N/A - Not available * - Not applicable
** - Penetrator broke up; see last table of this Appendix
Note: Exit angles greater than 90° are ricochet angles.

TABLE A2a. (Continued)

	STRIKING SPEED (m/s)	EXIT SPEED (m/s)	EXIT ANGLE (deg)	LOS PENETRATION (cm)	PERPENDICULAR PENETRATION (cm)	RECOVERED PENETRATOR MIN. DIA (cm)	RECOVERED PENETRATOR MAX. DIA (cm)	RECOVERED PENETRATOR MASS (g)	SHOT IDENTIFICATION
41	1572	909	0.5	C/P	C/P	N/A	N/A	**	FP-1-79-01-18-3
42	1600	927	0.5	C/P	C/P	N/A	N/A	**	FP-1-78-08-08-4
43	1606	927	0.3	C/P	C/P	N/A	N/A	**	FP-1-79-01-18-1
44	1607	934	0.2	C/P	C/P	N/A	N/A	**	FP-1-79-01-18-2
45	1615	942	0.6	C/P	C/P	N/A	N/A	**	FP-1-78-08-08-2
46	1625	939	0.5	C/P	C/P	N/A	N/A	**	FP-1-79-01-17-1
47	1626	948	0.8	C/P	C/P	N/A	N/A	**	FP-1-78-08-08-3
48	1629	N/A	N/A	C/P	C/P	N/A	N/A	**	FP-1-79-01-17-2
49	1634	962	0.5	C/P	C/P	N/A	N/A	**	FP-1-79-01-18-4

C/P - Complete penetration N/A - Not available * - Not applicable
** - Penetrator broke up; see last table of this Appendix
Note: Exit angles greater than 90° are ricochet angles.

TABLE A2b. Target Effects Data For 1/4 Inch Spheres Impacting 1/2 Inch Aluminum At 0 Degrees

PENETRATOR CHARACTERISTICS

SHAPE	- Sphere (Ball Bearing)
MATERIAL	- Steel
DIAMETER	- 0.635 cm.
MASS	- 1.044 g.
HARDNESS	- 65 Rc

TARGET CHARACTERISTICS

SHAPE	- (7.6 or 10) x 30 cm. Plate
MATERIAL	- Aluminum 2024-T351
THICKNESS	- 5.080 cm.
HARDNESS	- 153 BHN
IMPACT ANGLE	- 0°

	HOLE DIAMETERS ENTRANCE Min. (cm)	HOLE DIAMETERS ENTRANCE Max. (cm)	EXIT Min. (cm)	EXIT Max. (cm)	CRATER WIDTH (cm)	CRATER LENGTH (cm)	GROOVE WIDTH (cm)	GROOVE LENGTH (cm)	REAR SURFACE BULGE (cm)	SHOT IDENTIFICATION
1	0.53	0.53	*	*	0.53	0.53	*	*	0.00	FP-1-81-06-11-2
2	0.52	0.52	*	*	0.52	0.52	*	*	0.00	FP-1-81-06-10-2
3	0.54	0.54	*	*	0.54	0.54	*	*	0.00	FP-1-81-06-11-4
4	0.55	0.55	*	*	0.55	0.55	*	*	0.00	FP-1-81-06-09-1
5	0.58	0.58	*	*	0.58	0.58	*	*	0.00	FP-1-81-06-10-3
6	0.60	0.60	*	*	0.60	0.60	*	*	0.00	FP-1-81-06-10-1
7	0.69	0.69	*	*	0.69	0.69	*	*	0.00	FP-1-81-06-11-3
8	0.70	0.70	*	*	0.70	0.70	*	*	0.00	FP-1-81-06-08-1
9	0.70	0.70	*	*	0.70	0.70	*	*	0.00	FP-1-81-06-08-2
10	0.75	0.75	*	*	0.75	0.75	*	*	0.00	FP-1-81-06-11-1
11	0.80	0.80	*	*	0.80	0.80	*	*	0.04	FP-1-81-06-10-5
12	0.90	0.95	*	*	0.90	0.95	*	*	0.29	FP-1-81-06-03-2
13	0.88	0.88	*	*	0.88	0.88	*	*	0.27	FP-1-78-08-09-1
14	0.89	0.89	*	*	0.89	0.89	*	*	0.31	FP-1-78-08-02-1
15	0.92	0.92	*	*	0.92	0.92	*	*	0.35	FP-1-78-08-03-1
16	0.89	0.89	*	*	0.89	0.89	*	*	0.36	FP-1-78-08-10-1
17	0.95	0.95	*	*	0.95	0.95	*	*	0.41	FP-1-78-08-02-2
18	0.92	0.92	*	*	0.92	0.92	*	*	0.50	FP-1-78-08-11-3
19	0.90	0.90	*	*	1.00	0.90	*	*	0.45	FP-1-78-08-10-2
20	0.99	0.89	*	*	0.99	1.20	*	*	0.26	FP-1-78-08-09-2

N/A - Not available * - Not applicable

TABLE A2b. (Continued)

	HOLE DIAMETERS ENTRANCE Min. (cm)	Max. (cm)	EXIT Min. (cm)	Max. (cm)	CRATER WIDTH (cm)	LENGTH (cm)	GROOVE WIDTH (cm)	LENGTH (cm)	REAR SURFACE BULGE (cm)	SHOT IDENTIFICATION
21	0.92	0.92	0.58	0.58	0.79	1.13	*	*	*	FP-1-78-08-03-4
22	0.90	0.90	0.60	0.60	1.00	1.20	*	*	*	FP-1-81-06-03-3
23	0.92	0.92	0.58	0.58	1.07	1.16	*	*	*	FP-1-78-08-11-2
24	0.95	0.95	0.60	0.60	0.85	1.19	*	*	*	FP-1-78-08-03-2
25	0.93	0.93	0.57	0.57	1.14	1.20	*	*	*	FP-1-78-08-11-1
26	0.89	0.89	0.56	0.56	0.96	1.23	*	*	*	FP-1-78-08-10-3
27	1.00	1.00	0.60	0.60	1.00	1.20	*	*	*	FP-1-81-06-04-2
28	0.94	0.99	0.55	0.55	0.90	1.24	*	*	*	FP-1-78-08-03-3
29	0.90	1.00	0.60	0.60	1.00	1.20	*	*	*	FP-1-81-06-04-1
30	1.00	1.00	0.59	0.59	1.15	1.22	*	*	*	FP-1-79-01-22-1
31	1.00	1.00	0.59	0.59	1.17	1.17	*	*	*	FP-1-79-01-22-2
32	1.00	1.00	0.60	0.60	1.35	1.35	*	*	*	FP-1-81-06-02-1
33	1.00	1.00	0.59	0.59	1.22	1.22	*	*	*	FP-1-79-01-19-4
34	1.00	1.05	0.60	0.60	1.25	1.30	*	*	*	FP-1-81-06-03-1
35	1.00	1.00	0.59	0.59	1.20	1.20	*	*	*	FP-1-79-01-19-5
36	1.00	1.00	0.59	0.59	1.20	1.20	*	*	*	FP-1-79-01-19-3
37	1.00	1.00	0.59	0.59	1.19	1.19	*	*	*	FP-1-79-01-19-2
38	1.02	1.02	0.64	0.64	1.24	1.24	*	*	*	FP-1-79-01-18-5
39	1.07	1.19	0.63	0.63	1.21	1.26	*	*	*	FP-1-78-08-08-1
40	1.07	1.20	0.64	0.64	1.29	1.29	*	*	*	FP-1-79-01-19-1

N/A - Not available * - Not applicable

TABLE A2b. (Continued)

	HOLE DIAMETERS				CRATER		GROOVE		REAR SURFACE BULGE	SHOT IDENTIFICATION
	ENTRANCE		EXIT		WIDTH	LENGTH	WIDTH	LENGTH		
	Min. (cm)	Max. (cm)	Min. (cm)	Max. (cm)	(cm)	(cm)	(cm)	(cm)	(cm)	
41	1.08	1.08	0.64	0.64	1.29	1.29	*	*	*	FP-1-79-01-18-3
42	1.04	1.13	0.66	0.66	1.29	1.32	*	*	*	FP-1-78-08-08-4
43	1.09	1.09	0.64	0.64	1.24	1.30	*	*	*	FP-1-79-01-18-1
44	1.09	1.28	0.64	0.64	1.26	1.26	*	*	*	FP-1-79-01-18-2
45	1.08	1.08	0.65	0.65	1.28	1.28	*	*	*	FP-1-78-08-08-2
46	1.09	1.09	0.64	0.64	1.30	1.30	*	*	*	FP-1-79-01-17-1
47	1.09	1.10	0.65	0.65	1.30	1.30	*	*	*	FP-1-78-08-08-3
48	1.09	1.09	0.64	0.64	1.24	1.33	*	*	*	FP-1-79-01-17-2
49	1.10	1.10	0.64	0.64	1.32	1.32	*	*	*	FP-1-79-01-18-4

N/A - Not available   * - Not applicable

TABLE A3a. Target Effects Data For 1/4 Inch Spheres Impacting 2 Inch Aluminum At 0 Degrees

PENETRATOR CHARACTERISTICS

SHAPE	- Sphere (Ball Bearing)
MATERIAL	- Steel
DIAMETER	- 0.635 cm.
MASS	- 1.044 g.
HARDNESS	- 65 Rc

TARGET CHARACTERISTICS

SHAPE	- (7.6 or 10) x 30 cm. Plate
MATERIAL	- Aluminum 24S-T
THICKNESS	- 5.080 cm.
HARDNESS	- 163 BHN
IMPACT ANGLE	- 0°

	STRIKING SPEED (m/s)	EXIT SPEED (m/s)	EXIT ANGLE (deg)	LOS PENETRATION (cm)	PERPENDICULAR PENETRATION (cm)	RECOVERED PENETRATOR MIN. DIA (cm)	RECOVERED PENETRATOR MAX. DIA (cm)	RECOVERED PENETRATOR MASS (g)	SHOT IDENTIFICATION
1	212	43	176.4	0.09	0.09	0.634	0.634	1.043	FP-1-81-06-24-1
2	281	47	179.4	0.13	0.13	0.634	0.635	1.043	FP-1-81-06-23-4
3	359	52	179.6	0.20	0.20	0.634	0.634	1.043	FP-1-81-06-24-2
4	384	53	180.3	0.20	0.20	0.634	0.634	1.043	FP-1-81-06-23-3
5	406	53	179.8	0.23	0.23	0.634	0.634	1.044	FP-1-81-06-24-3
6	412	N/A	N/A	0.25	0.25	N/A	N/A	N/A	FP-1-81-06-23-2
7	472	N/A	N/A	0.32	0.32	0.635	0.636	1.043	FP-1-81-06-23-1
8	511	59	181.1	0.33	0.33	N/A	N/A	N/A	FP-1-81-06-25-3
9	587	66	182.3	0.41	0.41	0.634	0.634	1.044	FP-1-81-06-25-2
10	625	65	184.7	0.44	0.44	0.634	0.635	1.043	FP-1-81-06-25-1
11	696	69	179.7	0.51	0.51	0.631	0.635	1.044	FP-1-81-06-29-1
12	771	70	180.6	0.63	0.63	N/A	N/A	N/A	FP-1-81-06-29-2
13	786	68	180.6	0.63	0.63	N/A	N/A	N/A	FP-1-81-06-29-3
14	872	57	180.9	0.72	0.72	0.630	0.636	1.044	FP-1-81-06-29-4
15	891	38	186.7	0.73	0.73	0.628	0.638	1.043	FP-1-81-06-29-6
16	940	0	*	0.60	0.60	N/A	N/A	N/A	FP-1-81-06-30-1
17	975	0	*	0.68	0.68	N/A	N/A	N/A	FP-1-81-06-29-5
18	1305	0	*	1.30	1.30	N/A	N/A	N/A	FP-1-81-06-30-2
19	1707	0	*	1.66	1.66	N/A	N/A	N/A	FP-1-81-06-26-1

CP - Complete penetration N/A - Not available * - Not applicable

Note: Exit angles greater than 90° are ricochet angles.

TABLE A3b. Target Effects Data For 1/4 Inch Spheres Impacting 2 Inch Aluminum At 0 Degrees

PENETRATOR CHARACTERISTICS		TARGET CHARACTERISTICS	
SHAPE	- Sphere (Ball Bearing)	SHAPE	- (7.6 or 10) x 30 cm. Plate
MATERIAL	- Steel	MATERIAL	- Aluminum 24S-T
DIAMETER	- 0.635 cm.	THICKNESS	- 5.080 cm.
MASS	- 1.044 g.	HARDNESS	- 163 BHN
HARDNESS	- 65 Rc	IMPACT ANGLE	- 0°

	HOLE DIAMETERS				CRATER		GROOVE		REAR	SHOT
	ENTRANCE		EXIT		WIDTH	LENGTH	WIDTH	LENGTH	SURFACE BULGE	IDENTIFICATION
	Min. (cm)	Max. (cm)	Min. (cm)	Max. (cm)	(cm)	(cm)	(cm)	(cm)	(cm)	
1	0.53	0.53	0.53	0.53	0.53	0.53	*	*	*	FP-1-81-06-24-1
2	0.59	0.59	0.59	0.59	0.59	0.59	*	*	*	FP-1-81-06-24-2
3	0.63	0.64	0.63	0.64	0.63	0.64	*	*	*	FP-1-81-06-24-2
4	0.65	0.65	0.65	0.65	0.65	0.65	*	*	*	FP-1-81-06-23-3
5	0.64	0.70	0.64	0.70	0.64	0.70	*	*	*	FP-1-81-06-24-3
6	0.67	0.67	0.67	0.67	0.67	0.67	*	*	*	FP-1-81-06-23-2
7	0.73	0.74	0.73	0.74	0.73	0.74	*	*	*	FP-1-81-06-23-1
8	0.70	0.79	0.70	0.79	0.70	0.79	*	*	*	FP-1-81-06-25-3
9	0.70	0.82	0.70	0.82	0.70	0.82	*	*	*	FP-1-81-06-25-2
10	0.74	0.85	0.70	0.87	0.74	0.85	*	*	*	FP-1-81-06-29-1
11	0.70	0.87	0.70	0.87	0.70	0.87	*	*	*	FP-1-81-06-29-1
12	0.65	0.90	0.65	0.90	0.65	0.90	*	*	*	FP-1-81-06-29-2
13	0.65	0.95	0.65	0.95	0.65	0.95	*	*	*	FP-1-81-06-29-3
14	0.69	0.93	0.69	0.93	0.69	0.93	*	*	*	FP-1-81-06-29-4
15	0.65	0.95	0.65	0.95	0.65	0.95	*	*	*	FP-1-81-06-29-6
16	0.70	1.00	*	*	0.70	1.00	*	*	*	FP-1-81-06-29-5
17	0.65	1.15	*	*	0.65	1.15	*	*	*	FP-1-81-06-29-5
18	0.70	1.13	*	*	0.70	1.13	*	*	*	FP-1-81-06-30-2
19	0.90	1.15	*	*	0.90	1.15	*	*	*	FP-1-81-06-26-1

N/A - Not available * - Not applicable

TABLE A4a. Target Effects Data For 1/4 Inch Spheres Impacting 1/4 Inch Aluminum At 45 Degrees

PENETRATOR CHARACTERISTICS		TARGET CHARACTERISTICS	
SHAPE	- Sphere (Ball Bearing)	SHAPE	- (7.6 or 10) x 30 cm. Plate
MATERIAL	- Steel	MATERIAL	- Aluminum 2024-T351
DIAMETER	- 0.635 cm.	THICKNESS	- 0.635 cm.
MASS	- 1.044 g.	HARDNESS	- 143 BHN
HARDNESS	- 65 Rc	IMPACT ANGLE	- 45°

	STRIKING SPEED (m/s)	EXIT SPEED (m/s)	EXIT ANGLE (deg)	LOS PENETRATION (cm)	PERPENDICULAR PENETRATION (cm)	RECOVERED PENETRATOR MIN. DIA (cm)	RECOVERED PENETRATOR MAX. DIA (cm)	RECOVERED PENETRATOR MASS (g)	SHOT IDENTIFICATION
1	109	66	117.8	0.20	0.02	N/A	N/A	N/A	FP-1-81-12-02-1
2	187	99	120.7	0.23	0.06	N/A	N/A	N/A	FP-1-80-06-13-1
3	211	113	114.0	0.30	0.06	N/A	N/A	N/A	FP-1-81-12-01-2
4	220	N/A	N/A	0.25	0.07	N/A	N/A	N/A	FP-1-80-06-16-2
5	244	129	115.5	0.35	0.09	N/A	N/A	N/A	FP-1-81-12-01-1
6	323	144	120.2	0.40	0.11	N/A	N/A	N/A	FP-1-80-06-17-1
7	344	145	123.0	0.35	0.14	N/A	N/A	N/A	FP-1-80-06-17-3
8	368	147	126.8	0.41	0.16	N/A	N/A	N/A	FP-1-60-06-17-2
9	395	N/A	N/A	0.51	0.15	N/A	N/A	N/A	FP-1-80-06-11-1
10	445	149	127.7	0.55	0.22	N/A	N/A	N/A	FP-1-80-06-18-1
11	544	108	145.2	0.65	0.29	N/A	N/A	N/A	FP-1-80-06-19-1
12	615	52	188.3	0.78	0.38	N/A	N/A	N/A	FP-1-80-08-14-2
13	654	48	195.1	0.89	0.42	N/A	N/A	N/A	FP-1-80-06-19-2
14	673	27	232.6	0.97	0.44	N/A	N/A	N/A	FP-1-80-08-12-1
15	687	26	229.2	0.92	0.42	N/A	N/A	N/A	FP-1-80-08-14-1
16	716	9	201.7	1.03	0.55	N/A	N/A	N/A	FP-1-80-07-30-1
17	732	13	219.4	1.01	0.58	N/A	N/A	N/A	FP-1-80-08-13-2
18	754	N/A	N/A	C/P	C/P	N/A	N/A	N/A	FP-1-80-08-19-1
19	755	0	*	1.28	0.71	N/A	N/A	N/A	FP-1-80-08-26-1

C/P - Complete penetration N/A - Not available * - Not applicable
Note: Exit angles greater than 90° are ricochet angles.

TABLE A4a. (Continued)

	STRIKING SPEED (m/s)	EXIT SPEED (m/s)	EXIT ANGLE (deg)	LOS PENETRATION (cm)	PERPENDICULAR PENETRATION (cm)	RECOVERED PENETRATOR MIN. DIA (cm)	RECOVERED PENETRATOR MAX. DIA (cm)	RECOVERED PENETRATOR MASS (g)	SHOT IDENTIFICATION
20	775	100	9.9	C/P	C/P	N/A	N/A	N/A	FP-1-80-08-13-1
21	775	77	-0.9	C/P	C/P	N/A	N/A	N/A	FP-1-80-08-18-1
22	831	209	17.9	C/P	C/P	N/A	N/A	N/A	FP-1-80-08-25-2
23	857	276	27.6	C/P	C/P	N/A	N/A	N/A	FP-1-80-08-25-1
24	989	N/A	N/A	C/P	C/P	N/A	N/A	N/A	FP-1-80-08-22-1
25	1007	506	37.8	C/P	C/P	N/A	N/A	N/A	FP-1-80-08-22-2
26	1036	542	38.3	C/P	C/P	N/A	N/A	N/A	FP-1-80-08-28-1
27	1036	538	38.7	C/P	C/P	N/A	N/A	N/A	FP-1-80-09-11-1
28	1038	544	38.8	C/P	C/P	N/A	N/A	N/A	FP-1-80-09-10-1
29	1213	762	42.8	C/P	C/P	N/A	N/A	N/A	FP-1-80-09-15-1
30	1286	834	43.4	C/P	C/P	N/A	N/A	N/A	FP-1-80-09-15-2
31	1405	963	44.6	C/P	C/P	N/A	N/A	N/A	FP-1-80-09-16-1

C/P - Complete penetration N/A - Not available * - Not applicable
Note: Exit angles greater than 90° are ricochet angles.

TABLE A4b. Target Effects Data For 1/4 Inch Spheres Impacting 1/4 Inch Aluminum At 45 Degrees

PENETRATOR CHARACTERISTICS

SHAPE - Sphere (Ball Bearing)
MATERIAL - Steel
DIAMETER - 0.635 cm.
MASS - 1.044 g.
HARDNESS - 65 Rc

TARGET CHARACTERISTICS

SHAPE - (7.6 or 10) x 30 cm. Plate
MATERIAL - Aluminum 2024-T351
THICKNESS - 0.635 cm.
HARDNESS - 143 BHN
IMPACT ANGLE - 45°

	HOLE DIAMETERS ENTRANCE Min. (cm)	HOLE DIAMETERS ENTRANCE Max. (cm)	HOLE DIAMETERS EXIT Min. (cm)	HOLE DIAMETERS EXIT Max. (cm)	CRATER WIDTH (cm)	CRATER LENGTH (cm)	GROOVE WIDTH (cm)	GROOVE LENGTH (cm)	REAR SURFACE BULGE (cm)	SHOT IDENTIFICATION
1	*	*	*	*	F 0.32	F 0.40	0.32	0.40	0.00	FP-1-81-12-02-1
2	*	*	*	*	F 0.36	F 0.47	0.36	0.47	0.00	FP-1-80-06-13-1
3	*	*	*	*	F 0.45	F 0.61	0.45	0.61	0.00	FP-1-81-12-01-2
4	*	*	*	*	F 0.40	F 0.59	0.40	0.59	0.00	FP-1-80-06-16-2
5	*	*	*	*	F 0.50	F 0.69	0.50	0.69	0.00	FP-1-81-12-01-1
6	*	*	*	*	F 0.55	F 0.79	0.55	0.79	0.03	FP-1-80-06-17-1
7	*	*	*	*	F 0.61	F 0.79	0.56	0.79	0.04	FP-1-80-06-17-3
8	*	*	*	*	F 0.66	F 0.81	0.57	0.81	0.05	FP-1-80-06-17-2
9	*	*	*	*	F 0.77	F 0.95	0.59	0.95	0.05	FP-1-80-06-11-1
10	*	*	*	*	F 0.80	F 0.99	0.64	0.99	0.06	FP-1-80-06-18-1
11	*	*	*	*	F 0.75	F 1.20	0.69	1.14	0.10	FP-1-80-06-19-1
12	*	0.64	*	0.65	F 0.77	F 1.14	0.62	0.84	0.13	FP-1-80-08-14-2
13	*	0.70	*	0.64	F 0.81	F 1.21	0.69	1.21	0.16	FP-1-80-06-19-2
14	*	0.61	*	0.62	F 0.79	F 1.19	0.63	1.15	0.20	FP-1-80-08-12-1
15	*	0.65	*	0.74	F 0.87	F 1.22	0.67	0.96	0.20	FP-1-80-08-14-1
16	*	0.69	*	0.60	F 0.82	F 1.35	0.61	1.11	0.21	FP-1-80-07-30-1
17	*	0.59	*	0.60	F 0.87	F 1.12	0.62	1.12	0.26	FP-1-80-08-13-2
18	*	0.63	*	0.61	F 0.81 R 0.75	F 1.39 R 0.86	*	*	*	FP-1-80-08-19-1

F - the entrance side of the target plate; R - the exit side of the target plate
N/A - Not available * - Not applicable

TABLE A4b. (Continued)

	HOLE DIAMETERS ENTRANCE Min. (cm)	Max. (cm)	EXIT Min. (cm)	Max. (cm)	CRATER WIDTH (cm)	LENGTH (cm)	GROOVE WIDTH (cm)	LENGTH (cm)	REAR SURFACE BULGE (cm)	SHOT IDENTIFICATION
19	*	0.61	*	*	F 0.88	F 1.35	0.59	1.28	0.31	FP-1-80-08-26-1
20	*	0.60	*	0.61	F 0.94	F 1.30	*	*	*	FP-1-80-08-13-1
					R 0.98	R 1.10				
21	*	0.61	*	0.59	F 0.81	F 1.39	*	*	*	FP-1-80-08-18-1
					R 0.83	R 1.11				
22	*	0.60	*	0.61	F 0.92	F 1.30	*	*	*	FP-1-80-08-25-2
					R 0.81	R 1.20				
23	*	0.66	*	0.67	F 0.87	F 1.35	*	*	*	FP-1-80-08-25-1
					R 0.92	R 1.23				
24	*	0.67	*	0.60	F 0.92	F 1.30	*	*	*	FP-1-80-08-22-1
					R 0.93	R 0.61				
25	*	0.69	*	0.61	F 0.87	F 1.29	*	*	*	FP-1-80-08-22-2
					R 0.94	R 1.33				
26	*	0.60	*	0.59	F 0.97	F 1.31	*	*	*	FP-1-80-08-28-1
					R 0.89	R 1.40				
27	*	0.63	*	0.61	F 0.93	F 1.38	*	*	*	FP-1-80-09-11-1
					R 0.88	R 1.37				
28	*	0.62	*	0.61	F 0.90	F 1.33	*	*	*	FP-1-80-09-10-1
					R 0.95	R 1.48				

F - the entrance side of the target plate; R - the exit side of the target plate
N/A - Not available * - Not applicable

TABLE A4b. (Continued)

	HOLE DIAMETERS ENTRANCE Min. (cm)	HOLE DIAMETERS ENTRANCE Max. (cm)	HOLE DIAMETERS EXIT Min. (cm)	HOLE DIAMETERS EXIT Max. (cm)	CRATER WIDTH (cm)	CRATER LENGTH (cm)	GROOVE WIDTH (cm)	GROOVE LENGTH (cm)	REAR SURFACE BULGE (cm)	SHOT IDENTIFICATION
29	*	0.67	*	0.70	F 0.92 R 0.91	F 1.39 R 1.46	*	*	*	FP-1-80-09-15-1
30	*	0.68	*	0.62	F 0.98 R 0.88	F 1.31 R 1.48	*	*	*	FP-1-80-09-15-2
31	*	0.61	*	0.60	F 1.01 R 0.89	F 1.41 R 1.53	*	*	*	FP-1-80-09-16-1

F - the entrance side of the target plate; R - the exit side of the target plate
N/A - Not available * - Not applicable

TABLE A5a. Target Effects Data For 1/4 Inch Spheres Impacting 1/2 Inch Aluminum At 45 Degrees

PENETRATOR CHARACTERISTICS

SHAPE	- Sphere (Ball Bearing)
MATERIAL	- Steel
DIAMETER	- 0.635 cm.
MASS	- 1.044 g.
HARDNESS	- 65 Rc

TARGET CHARACTERISTICS

SHAPE	- (7.6 or 10) x 30 cm. Plate
MATERIAL	- Aluminum 2024-T351
THICKNESS	- 5.080 cm.
HARDNESS	- 153 BHN
IMPACT ANGLE	- 45°

	STRIKING SPEED (m/s)	EXIT SPEED (m/s)	EXIT ANGLE (deg)	LOS PENETRATION (cm)	PERPENDICULAR PENETRATION (cm)	RECOVERED PENETRATOR MIN. DIA (cm)	RECOVERED PENETRATOR MAX. DIA (cm)	RECOVERED PENETRATOR MASS (g)	SHOT IDENTIFICATION
1	64	N/A	N/A	0.14	0.01	N/A	N/A	N/A	FP-1-81-11-19-2
2	170	99	120.5	0.28	0.05	N/A	N/A	N/A	FP-1-81-11-24-2
3	192	107	118.3	0.28	0.04	N/A	N/A	N/A	FP-1-81-11-25-2
4	197	112	120.0	0.29	0.06	N/A	N/A	N/A	FP-1-81-11-19-1
5	218	119	118.9	0.38	0.08	N/A	N/A	N/A	FP-1-81-11-23-1
6	308	152	115.9	0.40	0.11	N/A	N/A	N/A	FP-1-81-11-18-1
7	325	150	127.7	0.40	0.14	N/A	N/A	N/A	FP-1-81-03-17-2
8	334	156	126.5	0.40	0.14	N/A	N/A	N/A	FP-1-81-03-19-1
9	362	156	130.5	0.48	0.16	N/A	N/A	N/A	FP-1-81-03-17-1
10	392	168	125.6	0.44	C.17	N/A	N/A	N/A	FP-1-81-03-16-3
11	492	166	127.0	0.62	0.23	N/A	N/A	N/A	FP-1-81-03-17-3
12	534	163	133.4	0.59	0.26	N/A	N/A	N/A	FP-1-81-03-16-1
13	647	141	136.6	0.69	0.30	N/A	N/A	N/A	FP-1-81-03-05-3
14	786	137	160.0	0.95	0.44	N/A	N/A	N/A	FP-1-81-03-05-2
15	815	122	158.8	1.00	0.44	N/A	N/A	N/A	FP-1-81-03-05-1
16	875	85	160.4	1.19	0.51	N/A	N/A	N/A	FP-1-81-03-02-2
17	947	92	172.6	1.21	0.60	N/A	N/A	N/A	FP-1-81-02-04-2
18	949	50	203.5	1.23	0.61	N/A	N/A	N/A	FP-1-81-03-02-1
19	1021	58	201.3	1.37	0.70	N/A	N/A	N/A	FP-1-81-02-04-1

C/P - Complete penetration N/A - Not available * - Not applicable
** - Penetrator broke up; see last table of this Appendix
Note: Exit angles greater than 90° are ricochet angles.

TABLE A5a. (Continued)

	STRIKING SPEED (m/s)	EXIT SPEED (m/s)	EXIT ANGLE (deg)	LOS PENETRATION (cm)	PERPENDICULAR PENETRATION (cm)	RECOVERED PENETRATOR MIN. DIA (cm)	MAX. DIA (cm)	MASS (g)	SHOT IDENTIFICATION
20	1032	43	197.3	1.42	0.71	N/A	N/A	N/A	FP-1-81-02-10-1
21	1058	38	194.6	1.50	0.69	N/A	N/A	N/A	FP-1-81-02-02-3
22	1093	31	227.5	1.56	0.78	N/A	N/A	N/A	FP-1-81-02-02-4
23	1136	23	223.3	1.64	N/A	N/A	N/A	N/A	FP-1-81-01-29-1
24	1136	0	*	N/A	N/A	N/A	N/A	N/A	FP-1-81-02-02-2
25	1187	0	*	1.72	0.85	N/A	N/A	N/A	FP-1-81-02-02-1
26	1235	0	*	1.86	N/A	N/A	N/A	N/A	FP-1-81-01-30-4
27	1244	0	*	1.96	N/A	N/A	N/A	N/A	FP-1-81-01-30-1
28	1269	0	*	2.20	1.41	N/A	N/A	N/A	FP-1-81-01-29-3
29	1273	28	-0.8	C/P	C/P	N/A	N/A	N/A	FP-1-81-01-29-2
30	1313	177	8.0	C/P	C/P	N/A	N/A	N/A	FP-1-81-01-30-3
31	1317	156	6.3	C/P	C/P	N/A	N/A	N/A	FP-1-81-03-20-1
32	1369	291	21.5	C/P	C/P	N/A	N/A	N/A	FP-1-81-01-30-2
33	1425	355	27.0	C/P	C/P	N/A	N/A	N/A	FP-1-81-03-23-1
34	1546	528	36.7	C/P	C/P	N/A	N/A	**	FP-1-81-03-23-2

C/P - Complete penetration N/A - Not available * - Not applicable
** - Penetrator broke up; see last table of this Appendix
Note: Exit angles greater than 90° are ricochet angles.

TABLE A5b. Target Effects Data For 1/4 Inch Spheres Impacting 1/2 Inch Aluminum At 45 Degrees

PENETRATOR CHARACTERISTICS

SHAPE	- Sphere (Ball Bearing)
MATERIAL	- Steel
DIAMETER	- 0.635 cm.
MASS	- 1.044 g.
HARDNESS	- 65 Rc

TARGET CHARACTERISTICS

SHAPE	- (7.6 or 10) x 30 cm. Plate
MATERIAL	- Aluminum 2024-T351
THICKNESS	- 5.080 cm.
HARDNESS	- 153 BHN
IMPACT ANGLE	- 45°

	HOLE DIAMETERS				CRATER		GROOVE		REAR SURFACE BULGE	SHOT IDENTIFICATION
	ENTRANCE		EXIT		WIDTH	LENGTH	WIDTH	LENGTH		
	Min. (cm)	Max. (cm)	Min. (cm)	Max. (cm)	(cm)	(cm)	(cm)	(cm)	(cm)	
1	*	*	*	*	F 0.26	F 0.28	0.26	0.28	0.00	FP-1-81-11-19-2
2	*	*	*	*	F 0.43	F 0.55	0.43	0.55	0.00	FP-1-81-11-24-2
3	*	*	*	*	F 0.45	F 0.56	0.45	0.56	0.00	FP-1-81-11-25-2
4	*	*	*	*	F 0.46	F 0.58	0.46	0.58	0.00	FP-1-81-11-19-1
5	*	*	*	*	F 0.51	F 0.76	0.51	0.76	0.00	FP-1-81-11-23-1
6	*	*	*	*	F 0.59	F 0.81	0.59	0.81	0.00	FP-1-81-11-18-1
7	*	*	*	*	F 0.55	F 0.80	0.55	0.80	0.00	FP-1-81-03-17-2
8	*	*	*	*	F 0.60	F 0.79	0.60	0.79	0.00	FP-1-81-03-19-1
9	*	*	*	*	F 0.62	F 0.96	0.62	0.96	0.00	FP-1-81-03-17-1
10	*	*	*	*	F 0.61	F 0.89	0.61	0.89	0.00	FP-1-81-03-16-3
11	*	*	*	*	F 0.72	F 1.15	0.72	1.15	0.00	FP-1-81-03-17-3
12	*	*	*	*	F 0.80	F 1.19	0.80	1.19	0.00	FP-1-81-03-16-1
13	*	*	*	*	F 0.97	F 1.38	0.97	1.38	0.00	FP-1-81-03-05-3
14	*	0.74	*	0.68	F 0.98	F 1.47	0.66	1.47	0.02	FP-1-81-03-05-2
15	*	0.74	*	0.64	F 0.93	F 1.62	0.65	1.45	0.01	FP-1-81-03-05-1
16	*	0.78	*	0.73	F 0.98	F 1.75	0.74	1.53	0.02	FP-1-81-03-02-2
17	*	0.81	*	0.60	F 1.00	F 1.64	0.68	1.51	0.04	FP-1-81-02-04-2
18	*	0.79	*	0.62	F 0.98	F 1.77	0.61	1.41	0.06	FP-1-81-03-02-1
19	*	0.74	*	0.76	F 1.26	F 1.76	0.76	1.37	0.09	FP-1-81-02-04-1

F - the entrance side of the target plate; R - the exit side of the target plate
N/A - Not available * - Not applicable

TABLE A5b. (Continued)

	HOLE DIAMETERS				CRATER		GROOVE		REAR SURFACE BULGE	SHOT IDENTIFICATION
	ENTRANCE		EXIT		WIDTH	LENGTH	WIDTH	LENGTH		
	Min. (cm)	Max. (cm)	Min. (cm)	Max. (cm)	(cm)	(cm)	(cm)	(cm)	(cm)	
20	*	0.81	*	0.64	F 0.93	F 1.71	0.69	1.60	0.11	FP-1-81-02-10-1
21	*	0.73	*	0.65	F 1.14	F 1.74	0.60	1.50	0.09	FP-1-81-02-02-3
22	*	0.71	*	0.62	F 1.20	F 1.73	0.62	1.56	0.12	FP-1-81-02-02-4
23	*	0.74	*	0.74	F 1.21	F 1.62	0.63	1.64	0.16	FP-1-81-01-29-1
24	*	0.71	*	*	F 1.00	F 1.71	0.61	N/A	0.17	FP-1-81-02-02-2
25	*	0.72	*	*	F 1.28	F 1.69	0.60	1.72	0.21	FP-1-81-02-02-1
26	*	0.72	*	*	F 1.26	F 1.62	0.60	1.86	0.31	FP-1-81-01-30-4
27	*	0.72	*	*	F 1.11	F 1.67	0.61	1.96	0.32	FP-1-81-01-30-1
28	*	0.72	*	*	F 1.07	F 1.52	0.60	2.20	0.52	FP-1-81-01-29-3
29	*	0.73	*	0.58	F 1.06	F 1.60	0.61	2.38	*	FP-1-81-01-29-2
					R 1.35	R 1.41				
30	*	0.69	*	0.57	F 1.20	F 1.66	0.57	2.20	*	FP-1-81-01-30-3
					R 1.32	R 1.62				
31	*	0.75	*	0.58	F 1.28	F 1.64	0.50	1.70	*	FP-1-81-03-20-1
					R 1.36	R 1.36				
2	*	0.72	*	0.60	F 1.08	F 1.70	0.60	1.88	*	FP-1-81-01-30-2
					R 1.31	R 1.86				
33	*	0.77	*	0.58	F 1.08	F 1.64	0.63	2.22	*	FP-1-81-03-23-1
					R 1.28	R 1.73				
34	*	0.84	*	0.59	F 1.44	F 1.55	0.67	1.93	*	FP-1-81-03-23-2
					R 1.38	R 1.82				

F - the entrance side of the target plate; R - the exit side of the target plate
N/A - Not available * - Not applicable

TABLE A6a. Target Effects Data For 1/4 Inch Spheres Impacting 2 Inch Aluminum At 45 Degrees

PENETRATOR CHARACTERISTICS		TARGET CHARACTERISTICS	
SHAPE	- Sphere (Ball Bearing)	SHAPE	- (7.6 or 10) x 30 cm. Plate
MATERIAL	- Steel	MATERIAL	- Aluminum 24S-T
DIAMETER	- 0.635 cm.	THICKNESS	- 5.080 cm.
MASS	- 1.044 g.	HARDNESS	- 163 BHN
HARDNESS	- 65 Rc	IMPACT ANGLE	- 45°

	STRIKING SPEED (m/s)	EXIT SPEED (m/s)	EXIT ANGLE (deg)	LOS PENETRATION (cm)	PERPENDICULAR PENETRATION (cm)	RECOVERED PENETRATOR MIN. DIA (cm)	MAX. DIA (cm)	MASS (g)	SHOT IDENTIFICATION
1	255	138	114.9	0.30	0.09	0.634	0.634	1.044	FP-1-81-07-10-6
2	303	154	118.3	0.34	0.12	0.634	0.634	1.044	FP-1-81-07-13-3
3	408	181	123.3	0.49	0.15	0.634	0.634	1.044	FP-1-81-07-10-5
4	451	183	128.4	0.54	0.18	0.634	0.634	1.044	FP-1-81-07-10-2
5	454	179	126.9	0.56	0.19	0.634	0.634	1.044	FP-1-81-07-13-2
6	552	180	137.0	0.60	0.24	0.634	0.634	1.044	FP-1-81-07-10-4
7	624	166	135.7	0.70	0.29	0.634	0.635	1.045	FP-1-81-07-10-3
8	655	168	138.1	0.73	0.32	0.634	0.634	1.044	FP-1-81-07-10-1
9	798	172	148.8	0.88	0.41	0.633	0.634	1.044	FP-1-81-07-02-2
10	857	144	154.9	0.98	0.43	0.632	0.636	1.044	FP-1-81-07-07-2
11	918	N/A	N/A	1.10	0.50	0.634	0.635	1.044	FP-1-81-07-02-1
12	927	N/A	N/A	1.10	0.50	0.634	0.637	1.044	FP-1-81-07-07-1
13	951	124	167.9	1.13	0.54	0.633	0.637	1.045	FP-1-81-07-08-4
14	989	107	181.9	1.26	0.56	0.631	0.635	1.044	FP-1-81-07-08-5
15	1075	57	198.1	1.30	0.67	0.632	0.636	1.045	FP-1-81-07-08-3
16	1165	46	198.3	1.40	0.74	0.634	0.638	1.044	FP-1-81-07-07-3
17	1222	52	187.6	1.51	0.81	0.623	0.641	1.044	FP-1-81-07-09-2
18	1233	48	205.6	1.56	0.82	0.626	0.638	1.044	FP-1-81-07-08-1
19	1247	54	207.1	1.57	0.82	0.634	0.640	1.044	FP-1-81-07-08-2

C/P - Complete penetration N/A - Not available * - Not applicable
Note: Exit angles greater than 90° are ricochet angles.

TABLE A6a. (Continued)

	STRIKING SPEED (m/s)	EXIT SPEED (m/s)	EXIT ANGLE (deg)	LOS PENETRATION (cm)	PERPENDICULAR PENETRATION (cm)	RECOVERED PENETRATOR MIN. DIA (cm)	RECOVERED PENETRATOR MAX. DIA (cm)	RECOVERED PENETRATOR MASS (g)	SHOT IDENTIFICATION
20	1267	0	*	1.46	0.78	N/A	N/A	N/A	FP-1-81-07-13-4
21	1277	41	225.4	1.68	0.86	N/A	N/A	N/A	FP-1-81-07-09-3
22	1293	39	200.2	1.67	0.92	0.623	0.642	1.044	FP-1-81-07-09-1
23	1293	24	231.2	1.69	0.88	0.620	0.639	1.045	FP-1-81-07-13-1
24	1317	0	*	N/A	N/A	N/A	N/A	N/A	FP-1-81-07-07-4
25	1346	11	*	1.85	0.95	0.625	0.642	1.044	FP-1-81-07-09-4
26	1413	0	*	2.13	N/A	N/A	N/A	N/A	FP-1-81-07-09-5

C/P - Complete penetration N/A - Not available * - Not applicable
Note: Exit angles greater than 90° are ricochet angles.

TABLE A6b. Target Effects Data For 1/4 Inch Spheres Impacting 2 Inch Aluminum At 45 Degrees

PENETRATOR CHARACTERISTICS

SHAPE	- Sphere (Ball Bearing)
MATERIAL	- Steel
DIAMETER	- 0.635 cm.
MASS	- 1.044 g.
HARDNESS	- 65 Rc

TARGET CHARACTERISTICS

SHAPE	- (7.6 or 10) x 30 cm. Plate
MATERIAL	- Aluminum 24S-T
THICKNESS	- 5.080 cm.
HARDNESS	- 163 BHN
IMPACT ANGLE	- 45°

	HOLE DIAMETERS				CRATER		GROOVE		REAR	SHOT
	ENTRANCE		EXIT		WIDTH	LENGTH	WIDTH	LENGTH	SURFACE BULGE	IDENTIFICATION
	Min. (cm)	Max. (cm)	Min. (cm)	Max. (cm)	(cm)	(cm)	(cm)	(cm)	(cm)	
1	*	*	*	*	0.44	0.59	0.44	0.59	*	FP-1-81-07-10-6
2	*	*	*	*	0.54	0.68	0.54	0.68	*	FP-1-81-07-13-3
3	*	*	*	*	0.58	0.90	0.58	0.90	*	FP-1-81-07-10-5
4	*	0.57	*	0.43	0.72	1.00	0.68	1.00	*	FP-1-81-07-10-2
5	*	0.61	*	0.53	0.78	1.08	0.73	1.08	*	FP-1-81-07-13-2
6	*	0.62	*	0.62	0.90	1.17	0.74	1.17	*	FP-1-81-07-10-4
7	*	0.64	*	0.64	0.83	1.36	0.73	1.36	*	FP-1-81-07-10-3
8	*	0.63	*	0.59	0.99	1.38	0.73	1.38	*	FP-1-81-07-10-1
9	*	0.61	*	0.61	0.99	1.57	0.73	1.41	*	FP-1-81-07-02-2
10	*	0.68	*	0.68	1.13	1.71	0.80	1.49	*	FP-1-81-07-07-2
11	*	0.62	*	0.73	1.13	1.94	0.90	1.64	*	FP-1-81-07-02-1
12	*	0.61	*	0.61	1.23	1.94	0.86	1.63	*	FP-1-81-07-07-1
13	*	0.69	*	0.70	1.49	1.85	0.75	1.12	*	FP-1-81-07-08-4
14	*	0.60	*	0.72	1.35	1.94	0.86	1.56	*	FP-1-81-07-08-5
15	*	0.73	*	0.73	1.68	2.21	0.85	1.62	*	FP-1-81-07-08-3
16	*	0.67	*	0.67	1.65	2.18	0.87	1.77	*	FP-1-81-07-07-3
17	*	0.70	*	0.85	1.76	2.39	0.93	1.87	*	FP-1-81-07-09-2
18	*	0.77	*	0.71	1.77	2.36	0.89	1.78	*	FP-1-81-07-08-1
19	*	0.75	*	0.91	1.75	2.37	0.91	1.80	*	FP 1-81-07-08-2

N/A - Not available * - Not applicable

TABLE A6b. (Continued)

	HOLE DIAMETERS				CRATER		GROOVE		REAR SURFACE BULGE	SHOT IDENTIFICATION
	ENTRANCE		EXIT		WIDTH	LENGTH	WIDTH	LENGTH		
	Min. (cm)	Max. (cm)	Min. (cm)	Max. (cm)	(cm)	(cm)	(cm)	(cm)	(cm)	
20	*	0.69	*	*	1.78	2.00	0.68	N/A	*	FP-1-81-07-13-4
21	*	0.73	*	0.82	1.69	2.22	0.90	1.82	*	FP-1-81-07-09-3
22	*	0.61	*	0.65	1.60	2.47	0.80	1.82	*	FP-1-81-07-09-1
23	*	0.68	*	0.68	2.02	2.36	0.85	1.73	*	FP-1-81-07-13-1
24	*	0.69	*	*	2.00	2.37	0.85	N/A	*	FP-1-81-07-07-4
25	*	0.71	*	0.64	1.68	2.02	0.84	1.93	*	FP-1-81-07-09-4
26	*	0.63	*	*	1.32	2.14	0.81	N/A	*	FP-1-81-07-09-5

N/A - Not available * - Not applicable

TABLE A7a. Target Effects Data For 1/4 Inch Spheres Impacting 1/4 Inch Aluminum At 60 Degrees

PENETRATOR CHARACTERISTICS		TARGET CHARACTERISTICS	
SHAPE	- Sphere (Ball Bearing)	SHAPE	- (7.6 or 10) x 30 cm. Plate
MATERIAL	- Steel	MATERIAL	- Aluminum 2024-T351
DIAMETER	- 0.635 cm.	THICKNESS	- 0.635 cm.
MASS	- 1.044 g.	HARDNESS	- 143 BHN
HARDNESS	- 65 Rc	IMPACT ANGLE	- 60°

	STRIKING SPEED (m/s)	EXIT SPEED (m/s)	EXIT ANGLE (deg)	LOS PENETRATION (cm)	PERPENDICULAR PENETRATION (cm)	RECOVERED PENETRATOR MIN. DIA (cm)	RECOVERED PENETRATOR MAX. DIA (cm)	RECOVERED PENETRATOR MASS (g)	SHOT IDENTIFICATION
1	118	93	110.0	0.19	0.03	0.634	0.635	1.044	FP-1-81-11-04-2
2	123	94	110.6	0.20	0.02	0.635	0.635	1.044	FP-1-81-11-04-1
3	168	125	110.0	0.25	0.04	0.634	0.635	1.044	FP-1-81-11-05-1
4	250	182	110.0	0.35	0.07	0.633	0.635	1.045	FP-1-81-09-11-5
5	339	230	108.9	0.37	0.08	0.633	0.635	1.044	FP-1-81-09-11-4
6	409	259	108.7	0.47	0.10	0.633	0.634	1.045	FP-1-81-09-11-3
7	440	270	110.0	0.50	0.13	0.633	0.634	1.044	FP-1-81-09-11-2
8	524	294	113.2	0.62	0.14	0.633	0.634	1.044	FP-1-81-09-11-1
9	569	302	115.2	0.70	0.18	0.633	0.634	1.045	FP-1-81-09-14-2
10	573	306	115.4	0.65	0.19	0.633	0.634	1.044	FP-1-81-09-14-1
11	634	303	116.0	0.73	0.22	0.633	0.634	1.044	FP-1-81-09-14-3
12	753	279	122.6	1.00	0.29	0.633	0.634	1.044	FP-1-81-09-14-4
13	864	205	134.8	1.20	0.39	0.633	0.634	1.044	FP-1-81-09-14-5
14	946	116	158.8	1.51	0.57	0.633	0.634	1.044	FP-1-81-09-14-6
15	953	111	171.7	1.62	0.50	0.633	0.634	1.044	FP-1-81-09-15-1
16	960	77	163.7	1.69	0.50	0.633	0.634	1.044	FP-1-81-09-15-2
17	997	43	181.1	1.90	0.59	0.633	0.634	1.044	FP-1-81-09-15-3
18	1016	2	163.1	1.79	0.67	0.633	0.634	1.044	FP-1-81-09-10-4
19	1025	4	188.8	1.08	0.70	0.633	0.634	1.044	FP-1-81-09-10-5

C/P - Complete penetration N/A - Not available * - Not applicable
** - Penetrator broke up; see last table of this Appendix
Note: Exit angles greater than 90° are ricochet angles.

TABLE A7a. (Continued)

	STRIKING SPEED (m/s)	EXIT SPEED (m/s)	EXIT ANGLE (deg)	LOS PENETRATION (cm)	PERPENDICULAR PENETRATION (cm)	RECOVERED PENETRATOR MIN. DIA (cm)	RECOVERED PENETRATOR MAX. DIA (cm)	RECOVERED PENETRATOR MASS (g)	SHOT IDENTIFICATION
20	1040	0	*	2.24	0.71	N/A	N/A	N/A	FP-1-81-09-10-2
21	1047	N/A	N/A	C/P	C/P	0.633	0.636	1.044	FP-1-81-09-10-3
22	1068	78	-7.6	C/P	C/P	0.633	0.634	1.044	FP-1-81-09-09-2
23	1073	85	6.2	C/P	C/P	0.633	0.634	1.045	FP-1-81-09-09-4
24	1082	N/A	N/A	C/P	C/P	0.633	0.634	1.044	FP-1-81-09-15-4
25	1142	264	34.5	C/P	C/P	0.633	0.634	1.045	FP-1-81-09-09-3
26	1239	459	48.3	C/P	C/P	0.633	0.634	1.044	FP-1-81-09-15-5
27	1335	599	53.3	C/P	C/P	0.633	0.634	1.044	FP-1-81-09-15-6
28	1341	595	53.7	C/P	C/P	0.634	0.635	1.044	FP-1-81-09-09-1
29	1635	926	59.8	C/P	C/P	*	*	**	FP-1-81-09-15-7

C/P - Complete penetration N/A - Not available * - Not applicable
** - Penetrator broke up; see last table of this Appendix
Note: Exit angles greater than 90° are ricochet angles.

TABLE A7b. Target Effects Data For 1/4 Inch Spheres Impacting 1/4 Inch Aluminum At 60 Degrees

PENETRATOR CHARACTERISTICS		TARGET CHARACTERISTICS	
SHAPE	- Sphere (Ball Bearing)	SHAPE	- (7.6 or 10) x 30 cm. Plate
MATERIAL	- Steel	MATERIAL	- Aluminum 2024-T351
DIAMETER	- 0.635 cm.	THICKNESS	- 0.635 cm.
MASS	- 1.044 g.	HARDNESS	- 143 BHN
HARDNESS	- 65 Rc	IMPACT ANGLE	- 60°

	HOLE DIAMETERS ENTRANCE Min. (cm)	HOLE DIAMETERS ENTRANCE Max. (cm)	EXIT Min. (cm)	EXIT Max. (cm)	CRATER WIDTH (cm)	CRATER LENGTH (cm)	GROOVE WIDTH (cm)	GROOVE LENGTH (cm)	REAR SURFACE BULGE (cm)	SHOT IDENTIFICATION
1	*	*	*	*	F 0.29	F 0.38	0.29	0.38	0.00	FP-1-81-11-04-2
2	*	*	*	*	F 0.30	F 0.40	0.30	0.40	0.00	FP-1-81-11-04-1
3	*	*	*	*	F 0.36	F 0.50	0.36	0.50	0.00	FP-1-81-11-05-1
4	*	*	*	*	F 0.45	F 0.64	0.45	0.64	0.00	FP-1-81-09-11-5
5	*	*	*	*	F 0.47	F 0.79	0.47	0.79	0.00	FP-1-81-09-11-4
6	*	*	*	*	F 0.56	F 0.99	0.56	0.99	0.00	FP-1-81-09-11-3
7	*	*	*	*	F 0.56	F 1.09	0.56	1.09	0.01	FP-1-81-09-11-2
8	*	*	*	*	F 0.66	F 1.29	0.66	1.29	0.01	FP-1-81-09-11-1
9	*	*	*	*	F 0.65	F 1.38	0.65	1.38	0.04	FP-1-81-09-14-2
10	*	*	*	*	F 0.65	F 1.42	0.65	1.42	0.05	FP-1-81-09-14-1
11	*	*	*	*	F 0.70	F 1.56	0.70	1.56	0.08	FP-1-81-09-14-3
12	*	*	*	*	F 0.90	F 1.91	0.80	1.91	0.09	FP-1-81-09-14-4
13	*	*	*	*	F 0.90	F 2.12	0.77	2.02	0.13	FP-1-81-09-14-5
14	*	0.66	*	0.69	F 0.98	F 2.23	0.72	2.18	0.22	FP-1-81-09-14-6
15	*	0.66	*	0.66	F 0.92	F 2.25	0.70	2.16	0.26	FP-1-81-09-15-1
16	*	0.69	*	0.60	F 0.91	F 2.33	0.65	2.14	0.19	FP-1-81-09-15-2
17	*	0.59	*	0.60	F 1.00	F 2.37	0.73	2.25	0.33	FP-1-81-09-15-3
18	*	0.61	*	*	F 1.01	F 2.40	0.70	2.23	0.39	FP-1-81-09-10-4
19	*	0.69	*	*	F 0.89	F 2.27	0.75	2.24	0.43	FP-1-81-09-10-5

F - the entrance side of the target plate; R - the exit side of the target plate
N/A - Not available * - Not applicable

TABLE A7b. (Continued)

	HOLE DIAMETERS ENTRANCE Min. (cm)	HOLE DIAMETERS ENTRANCE Max. (cm)	HOLE DIAMETERS EXIT Min. (cm)	HOLE DIAMETERS EXIT Max. (cm)	CRATER WIDTH (cm)	CRATER LENGTH (cm)	GROOVE WIDTH (cm)	GROOVE LENGTH (cm)	REAR SURFACE BULGE (cm)	SHOT IDENTIFICATION
20	*	0.62	*	*	F 1.00	F 2.34	0.60	2.14	0.49	FP-1-81-09-10-2
21	*	0.62	*	0.54	F 1.03	F 2.31	*	*	*	FP-1-81-09-10-3
					R 1.02	R 1.42				
22	*	0.63	*	0.54	F 1.03	F 2.29	*	*	*	FP-1-81-09-09-2
					R 1.04	R 1.57				
23	*	0.70	*	0.66	F 1.04	F 2.32	*	*	*	FP-1-81-09-09-4
					R 0.87	R 1.69				
24	*	0.69	*	0.58	F 1.08	F 2.31	*	*	*	FP-1-81-09-15-4
					R 1.07	R 1.90				
25	*	0.56	*	0.59	F 1.07	F 2.27	*	*	*	FP-1-81-09-09-3
					R 1.04	R 1.89				
26	*	0.68	*	0.59	F 1.07	F 2.09	*	*	*	FP-1-81-09-15-5
					R 1.03	R 1.97				
27	*	0.66	*	0.56	F 1.16	F 2.18	*	*	*	FP-1-81-09-15-6
					R 1.05	R 2.02				
28	*	0.68	*	0.61	F 1.11	F 2.23	*	*	*	FP-1-81-09-09-1
					R 1.07	R 2.09				
29	*	0.69	*	0.58	F 1.24	F 2.19	*	*	*	FP-1-81-09-15-7
					R 1.12	R 2.18				

F - the entrance side of the target plate; R - the exit side of the target plate
N/A - Not available * - Not applicable

TABLE A8a. Target Effects Data For 1/4 Inch Spheres Impacting 1/2 Inch Aluminum At 60 Degrees

PENETRATOR CHARACTERISTICS		TARGET CHARACTERISTICS	
SHAPE	- Sphere (Ball Bearing)	SHAPE	- (7.6 or 10) x 30 cm. Plate
MATERIAL	- Steel	MATERIAL	- Aluminum 2024-T351
DIAMETER	- 0.635 cm.	THICKNESS	- 5.080 cm.
MASS	- 1.044 g.	HARDNESS	- 153 BHN
HARDNESS	- 65 Rc	IMPACT ANGLE	- 60°

	STRIKING SPEED (m/s)	EXIT SPEED (m/s)	EXIT ANGLE (deg)	LOS PENETRATION (cm)	PERPENDICULAR PENETRATION (cm)	RECOVERED PENETRATOR MIN. DIA (cm)	RECOVERED PENETRATOR MAX. DIA (cm)	RECOVERED PENETRATOR MASS (g)	SHOT IDENTIFICATION
1	89	N/A	N/A	0.16	0.01	0.634	0.635	1.044	FP-1-81-10-07-3
2	126	106	96.4	0.21	0.02	0.634	0.635	1.044	FP-1-81-11-03-4
3	190	N/A	N/A	0.26	0.03	0.634	0.635	1.044	FP-1-81-11-03-2
4	226	165	110.1	0.32	0.06	0.634	0.635	1.044	FP-1-81-11-03-3
5	234	N/A	N/A	0.34	0.08	0.634	0.635	1.044	FP-1-81-10-30-4
6	254	N/A	N/A	0.34	0.08	0.634	0.635	1.044	FP-1-81-11-03-1
7	313	219	110.8	0.40	0.08	0.634	0.635	1.044	FP-1-81-10-30-2
8	315	219	110.5	0.39	0.08	0.634	0.635	1.045	FP-1-81-10-09-4
9	347	232	108.6	0.37	0.09	0.634	0.635	1.046	FP-1-81-10-09-3
10	391	256	110.2	0.46	0.10	0.634	0.635	1.046	FP-1-81-10-07-2
11	408	262	110.8	0.50	0.09	0.634	0.635	1.044	FP-1-81-10-09-2
12	463	N/A	N/A	0.53	0.14	0.634	0.635	1.044	FP-1-81-10-09-1
13	477	290	113.0	0.57	0.13	0.634	0.635	1.046	FP-1-81-10-07-1
14	662	335	116.6	0.72	0.20	0.635	0.635	1.045	FP-1-81-10-01-1
15	754	339	118.3	0.95	0.24	0.634	0.635	1.045	FP-1-81-10-01-4
16	830	332	122.3	1.02	0.28	0.634	0.635	1.044	FP-1-81-10-01-3
17	989	307	128.9	1.25	0.36	0.634	0.635	1.045	FP-1-81-10-01-5
18	1103	257	133.1	1.47	0.45	0.632	0.635	1.045	FP-1-81-10-01-6
19	1387	94	175.5	2.17	0.65	0.635	0.642	1.045	FP-1-81-10-02-1

C/P - Complete penetration N/A - Not available * - Not applicable
** - Penetrator broke up; see last table of this Appendix
Note: Exit angles greater than 90° are ricochet angles.

TABLE A8a. (Continued)

	STRIKING SPEED (m/s)	EXIT SPEED (m/s)	EXIT ANGLE (deg)	LOS PENETRATION (cm)	PERPENDICULAR PENETRATION (cm)	RECOVERED PENETRATOR MIN. DIA (cm)	RECOVERED PENETRATOR MAX. DIA (cm)	RECOVERED PENETRATOR MASS (g)	SHOT IDENTIFICATION
20	1453	45	186.4	2.30	0.75	0.629	0.640	1.045	FP-1-81-10-05-1
21	1544	47	214.2	1.58	0.79	0.633	0.640	1.045	FP-1-81-10-01-7
22	1567	31	230.9	2.55	0.82	0.618	0.638	1.044	FP-1-81-10-02-4
23	1591	N/A	N/A	2.71	0.92	0.626	0.642	1.044	FP-1-81-10-02-3
24	1625	30	234.2	2.82	N/A	0.613	0.642	1.041	FP-1-81-10-06-2
25	1636	24	237.0	2.81	N/A	0.612	0.640	1.043	FP-1-81-10-05-2
26	1649	N/A	N/A	3.06	0.82	*	*	**	FP-1-81-10-05-4
27	1651	13	223.3	2.79	N/A	0.621	0.644	1.037	FP-1-81-10-06-1
28	1696	28	196.2	2.97	0.89	*	*	**	FP-1-81-10-05-3
29	1709	N/A	N/A	1.79	0.79	*	*	**	FP-1-81-11-10-2
30	1728	54	180.3	2.96	0.81	*	*	**	FP-1-81-10-06-3
31	1748	68	181.1	N/A	0.87	*	*	**	FP-1-81-10-08-2
32	1749	N/A	N/A	1.68	0.80	*	*	**	FP-1-81-11-10-1
33	1754	N/A	N/A	1.70	0.80	*	*	**	FP-1-81-11-09-1
34	1757	75	179.5	N/A	0.83	*	*	**	FP-1-81-10-08-1
35	1766	N/A	N/A	1.80	0.80	*	*	**	FP-1-81-11-09-7
36	1787	N/A	N/A	N/A	0.85	*	*	**	FP-1-81-10-06-4
37	1801	N/A	N/A	1.73	0.86	*	*	**	FP-1-81-11-06-1
38	1805	N/A	N/A	1.72	0.89	*	*	**	FP-1-81-11-06-2

C/P - Complete penetration N/A - Not available * - Not applicable
** - Penetrator broke up; see last table of this Appendix
Note: Exit angles greater than 90° are ricochet angles.

TABLE A8b. Target Effects Data For 1/4 Inch Spheres Impacting 1/2 Inch Aluminum At 60 Degrees

PENETRATOR CHARACTERISTICS		TARGET CHARACTERISTICS	
SHAPE	- Sphere (Ball Bearing)	SHAPE	- (7.6 or 10) x 30 cm. Plate
MATERIAL	- Steel	MATERIAL	- Aluminum 2024-T351
DIAMETER	- 0.635 cm.	THICKNESS	- 5.080 cm.
MASS	- 1.044 g.	HARDNESS	- 153 BHN
HARDNESS	- 65 Rc	IMPACT ANGLE	- 60°

	HOLE DIAMETERS ENTRANCE Min. (cm)	HOLE DIAMETERS ENTRANCE Max. (cm)	HOLE DIAMETERS EXIT Min. (cm)	HOLE DIAMETERS EXIT Max. (cm)	CRATER WIDTH (cm)	CRATER LENGTH (cm)	GROOVE WIDTH (cm)	GROOVE LENGTH (cm)	REAR SURFACE BULGE (cm)	SHOT IDENTIFICATION
1	*	*	*	*	0.25	0.32	0.25	0.32	0.00	FP-1-81-10-07-3
2	*	*	*	*	0.30	0.42	0.30	0.42	0.00	FP-1-81-11-03-4
3	*	*	*	*	0.39	0.52	0.39	0.52	0.00	FP-1-81-11-03-2
4	*	*	*	*	0.45	0.63	0.45	0.63	0.00	FP-1-81-11-03-3
5	*	*	*	*	0.46	0.67	0.46	0.67	0.00	FP-1-81-10-30-4
6	*	*	*	*	0.47	0.68	0.47	0.68	0.00	FP-1-81-11-03-1
7	*	*	*	*	0.53	0.80	0.53	0.80	0.00	FP-1-81-10-30-2
8	*	*	*	*	0.48	0.79	0.48	0.79	0.00	FP-1-81-10-09-4
9	*	*	*	*	0.53	0.87	0.53	0.87	0.00	FP-1-81-10-09-3
10	*	*	*	*	0.58	0.96	0.58	0.96	0.00	FP-1-81-10-07-2
11	*	*	*	*	0.58	1.00	0.58	1.00	0.00	FP-1-81-10-09-2
12	*	*	*	*	0.71	1.16	0.56	1.16	0.00	FP-1-81-10-09-1
13	*	*	*	*	0.60	1.19	0.60	1.19	0.00	FP-1-81-10-07-1
14	*	*	*	*	0.74	1.55	0.74	1.55	0.00	FP-1-81-10-01-1
15	*	*	*	*	0.82	1.74	0.82	1.74	0.00	FP-1-81-10-01-4
16	*	*	*	*	0.95	1.90	0.95	1.90	0.00	FP-1-81-10-01-3
17	*	0.64	*	0.67	1.12	2.23	0.78	2.14	0.02	FP-1-81-10-01-5
18	*	0.91	*	0.69	1.21	2.45	0.78	2.45	0.05	FP-1-81-10-01-6
19	*	0.87	*	0.64	1.28	2.73	0.50	2.64	0.10	FP-1-81-10-02-1

N/A - Not available * - Not applicable

TABLE A8b. (Continued)

	HOLE DIAMETERS				CRATER		GROOVE		REAR	SHOT
	ENTRANCE		EXIT		WIDTH	LENGTH	WIDTH	LENGTH	SURFACE BULGE	IDENTIFICATION
	Min. (cm)	Max. (cm)	Min. (cm)	Max. (cm)	(cm)	(cm)	(cm)	(cm)	(cm)	
20	*	0.73	*	0.71	1.35	2.91	0.76	2.91	0.09	FP-1-81-10-05-1
21	*	0.81	*	0.65	1.36	2.95	0.81	2.78	0.14	FP-1-81-10-01-7
22	*	0.65	*	0.55	1.37	2.94	0.71	2.67	0.16	FP-1-81-10-02-4
23	*	0.71	*	0.64	1.52	2.97	0.84	2.46	0.19	FP-1-81-01-02-3
24	*	0.75	*	0.60	1.36	2.91	0.82	3.05	0.19	FP-1-81-10-06-2
25	*	0.71	*	0.63	1.41	2.99	0.64	2.91	0.18	FP-1-81-10-05-2
26	*	0.73	*	0.67	1.40	3.16	0.73	3.16	0.21	FP-1-81-10-05-4
27	*	0.71	*	0.65	1.40	2.98	0.80	2.89	0.20	FP-1-81-10-06-1
28	*	0.73	*	0.73	1.50	3.03	0.88	2.97	0.19	FP-1-81-10-05-3
29	*	0.69	*	*	1.62	2.69	0.71	1.76	0.13	FP-1-81-11-10-2
30	*	0.76	*	0.79	1.46	2.94	0.85	2.94	0.16	FP-1-81-10-06-3
31	*	0.89	*	N/A	1.68	3.00	0.72	N/A	0.22	FP-1-81-10-08-2
32	*	0.69	*	*	1.62	2.71	0.81	1.60	0.16	FP-1-81-11-10-1
33	*	0.81	*	*	1.68	2.63	0.81	1.56	0.17	FP-1-81-11-09-1
34	*	0.82	*	N/A	1.63	2.91	0.64	N/A	0.20	FP-1-81-10-08-1
35	*	0.84	*	*	1.69	2.58	0.84	1.55	0.15	FP-1-81-11-09-2
36	*	0.85	*	N/A	1.79	2.80	0.99	N/A	0.19	FP-1-81-10-06-4
37	*	0.75	*	*	1.83	3.04	1.13	1.51	0.17	FP-1-81-11-06-1
38	*	0.76	*	*	1.69	2.57	0.94	1.58	0.17	FP-1-81-11-06-2

N/A - Not available * - Not applicable

TABLE A9a. Target Effects Data For 1/4 Inch Spheres Impacting 2 Inch Aluminum At 60 Degrees

PENETRATOR CHARACTERISTICS		TARGET CHARACTERISTICS	
SHAPE	- Sphere (Ball Bearing)	SHAPE	- (7.6 or 10) x 30 cm. Plate
MATERIAL	- Steel	MATERIAL	- Aluminum 24S-T
DIAMETER	- 0.635 cm.	THICKNESS	- 5.080 cm.
MASS	- 1.044 g.	HARDNESS	- 163 BHN
HARDNESS	- 65 Rc	IMPACT ANGLE	- 60°

	STRIKING SPEED (m/s)	EXIT SPEED (m/s)	EXIT ANGLE (deg)	LOS PENETRATION (cm)	PERPENDICULAR PENETRATION (cm)	RECOVERED PENETRATOR MIN. DIA (cm)	RECOVERED PENETRATOR MAX. DIA (cm)	RECOVERED PENETRATOR MASS (g)	SHOT IDENTIFICATION
1	257	184	112.2	0.32	0.06	0.633	0.634	1.042	FP-1-81-11-12-3
2	389	254	112.6	0.48	0.11	0.634	0.635	1.044	FP-1-81-11-12-1
3	517	304	114.1	0.62	0.12	0.634	0.635	1.043	FP-1-81-11-12-2

C/P - Complete penetration N/A - Not available * - Not applicable
Note: Exit angles greater than 90° are ricochet angles.

TABLE A9b. Target Effects Data For 1/4 Inch Spheres Impacting 2 Inch Aluminum At 60 Degrees

PENETRATOR CHARACTERISTICS		TARGET CHARACTERISTICS	
SHAPE	- Sphere (Ball Bearing)	SHAPE	- (7.6 or 10) x 30 cm. Plate
MATERIAL	- Steel	MATERIAL	- Aluminum 24S-T
DIAMETER	- 0.635 cm.	THICKNESS	- 5.080 cm.
MASS	- 1.044 g.	HARDNESS	- 163 BHN
HARDNESS	- 65 Rc	IMPACT ANGLE	- 60°

	HOLE DIAMETERS				CRATER		GROOVE		REAR SURFACE BULGE	SHOT IDENTIFICATION
	ENTRANCE		EXIT		WIDTH	LENGTH	WIDTH	LENGTH		
	Min. (cm)	Max. (cm)	Min. (cm)	Max. (cm)	(cm)	(cm)	(cm)	(cm)	(cm)	
1	*	*	*	*	0.47	0.64	0.47	0.64	*	FP-1-81-11-12-3
2	*	*	*	*	0.51	0.96	0.51	0.96	*	FP-1-81-11-12-1
3	*	*	*	*	0.61	1.24	0.61	1.24	*	FP-1-81-11-12-2

N/A - Not available * - Not applicable

TABLE A10a. Target Effects Data For 15/32 Inch Spheres Impacting 1/4 Inch Aluminum At 0 Degrees

PENETRATOR CHARACTERISTICS		TARGET CHARACTERISTICS	
SHAPE	- Sphere (Ball Bearing)	SHAPE	- (7.6 or 10) x 30 cm. Plate
MATERIAL	- Steel	MATERIAL	- Aluminum 2024-T351
DIAMETER	- 1.191 cm.	THICKNESS	- 0.635 cm.
MASS	- 6.888 g.	HARDNESS	- 143 BHN
HARDNESS	- 65 Rc	IMPACT ANGLE	- 0°

	STRIKING SPEED (m/s)	EXIT SPEED (m/s)	EXIT ANGLE (deg)	LOS PENETRATION (cm)	PERPENDICULAR PENETRATION (cm)	RECOVERED PENETRATOR MIN. DIA (cm)	RECOVERED PENETRATOR MAX. DIA (cm)	RECOVERED PENETRATOR MASS (g)	SHOT IDENTIFICATION
1	143	18	184.6	0.13	0.13	1.190	1.191	6.891	FP-1-81-08-20-2
2	267	24	182.7	0.27	0.27	1.189	1.191	6.888	FP-1-81-08-20-1
3	412	12	180.2	0.64	0.64	1.190	1.191	6.888	FP-1-81-08-18-4
4	415	N/A	N/A	0.64	0.64	1.190	1.191	6.888	FP-1-81-08-19-3
5	419	20	182.9	0.64	0.64	1.189	1.190	6.888	FP-1-81-08-20-3
6	425	N/A	N/A	C/P	C/P	1.190	1.191	6.888	FP-1-81-08-18-6
7	439	122	-7.1	C/P	C/P	1.190	1.191	6.888	FP-1-81-08-19-2
8	441	138	5.0	C/P	C/P	1.189	1.190	6.888	FP-1-81-08-21-2
9	447	156	-2.7	C/P	C/P	1.189	1.190	6.888	FP-1-81-08-19-1
10	473	N/A	N/A	C/P	C/P	1.190	1.191	6.888	FP-1-81-08-21-1
11	475	227	1.4	C/P	C/P	1.190	1.191	6.888	FP-1-81-08-18-5
12	578	368	0.4	C/P	C/P	1.189	1.191	6.888	FP-1-81-08-18-3
13	744	566	0.4	C/P	C/P	1.186	1.192	6.888	FP-1-81-08-18-2
14	927	765	0.5	C/P	C/P	1.180	1.193	6.888	FP-1-81-08-21-4
15	1025	866	0.5	C/P	C/P	1.173	1.194	6.885	FP-1-81-08-21-5
16	1039	880	1.0	C/P	C/P	*	*	**	FP-1-81-08-21-3

C/P - Complete penetration N/A - Not available * - Not applicable
** - Penetrator broke up; see last table of this Appendix
Note: Exit angles greater than 90° are ricochet angles.

TABLE A10b. Target Effects Data For 15/32 Inch Spheres Impacting 1/4 Inch Aluminum At 0 Degrees

PENETRATOR CHARACTERISTICS		TARGET CHARACTERISTICS	
SHAPE	- Sphere (Ball Bearing)	SHAPE	- (7.6 or 10) x 30 cm. Plate
MATERIAL	- Steel	MATERIAL	- Aluminum 2024-T351
DIAMETER	- 1.191 cm.	THICKNESS	- 0.635 cm.
MASS	- 6.888 g.	HARDNESS	- 143 BHN
HARDNESS	- 65 Rc	IMPACT ANGLE	- 0°

	HOLE DIAMETERS				CRATER		GROOVE		REAR	SHOT
	ENTRANCE		EXIT		WIDTH	LENGTH	WIDTH	LENGTH	SURFACE BULGE	IDENTIFICATION
	Min. (cm)	Max. (cm)	Min. (cm)	Max. (cm)	(cm)	(cm)	(cm)	(cm)	(cm)	
1	0.63	0.63	0.63	0.63	0.63	0.63	*	*	0.11	FP-1-81-08-20-2
2	0.99	0.99	0.99	0.99	0.99	0.99	*	*	0.21	FP-1-81-08-20-1
3	1.19	1.19	0.94	0.94	1.19	1.19	*	*	*	FP-1-81-08-18-4
4	1.17	1.17	1.17	1.17	1.17	1.17	*	*	*	FP-1-81-08-19-3
5	1.19	1.19	1.19	1.19	1.19	1.19	*	*	*	FP-1-81-08-20-3
6	1.19	1.24	1.19	1.19	1.40	1.62	*	*	*	FP-1-81-08-18-6
7	1.24	1.24	1.15	1.15	1.24	1.79	*	*	*	FP-1-81-08-19-2
8	1.20	1.34	1.17	1.17	1.29	2.00	*	*	*	FP-1-81-08-21-2
9	1.24	1.24	1.19	1.19	1.28	1.80	*	*	*	FP-1-81-08-19-1
10	1.26	1.26	1.16	1.16	1.20	1.89	*	*	*	FP-1-81-08-21-1
11	1.24	1.39	1.20	1.20	1.31	1.78	*	*	*	FP-1-81-08-18-5
12	1.25	1.39	1.15	1.15	1.59	1.80	*	*	*	FP-1-81-08-18-3
13	1.40	1.49	1.16	1.16	1.59	1.64	*	*	*	FP-1-81-08-18-2
14	1.49	1.49	1.16	1.16	1.68	1.68	*	*	*	FP-1-81-08-21-4
15	1.48	1.52	1.16	1.16	1.72	1.72	*	*	*	FP-1-81-08-21-5
16	1.44	1.59	1.14	1.14	1.73	1.73	*	*	*	FP-1-81-08-21-3

N/A - Not available * - Not applicable

TABLE A11a. Target Effects Data For 15/32 Inch Spheres Impacting 1/2 Inch Aluminum At 0 Degrees

PENETRATOR CHARACTERISTICS		TARGET CHARACTERISTICS	
SHAPE	- Sphere (Ball Bearing)	SHAPE	- (7.6 or 10) x 30 cm. Plate
MATERIAL	- Steel	MATERIAL	- Aluminum 2024-T351
DIAMETER	- 1.191 cm.	THICKNESS	- 5.080 cm.
MASS	- 6.888 g.	HARDNESS	- 153 BHN
HARDNESS	- 65 Rc	IMPACT ANGLE	- 0°

	STRIKING SPEED (m/s)	EXIT SPEED (m/s)	EXIT ANGLE (deg)	LOS PENETRATION (cm)	PERPENDICULAR PENETRATION (cm)	RECOVERED PENETRATOR MIN. DIA (cm)	RECOVERED PENETRATOR MAX. DIA (cm)	RECOVERED PENETRATOR MASS (g)	SHOT IDENTIFICATION
1	329	5	178.5	0.42	0.42	1.190	1.191	6.888	FP-1-81-06-16-4
2	427	6	179.2	0.56	0.56	1.190	1.191	6.890	FP-1-81-06-16-3
3	476	6	186.0	0.70	0.70	1.190	1.190	6.888	FP-1-81-06-16-2
4	500	12	179.6	0.72	0.72	1.190	1.190	6.888	FP-1-81-06-16-1
5	547	N/A	N/A	0.84	0.84	1.188	1.190	6.888	FP-1-81-06-15-4
6	591	56	-2.6	C/P	C/P	1.188	1.191	6.888	FP-1-81-06-15-3
7	637	154	-0.4	C/P	C/P	1.188	1.191	6.889	FP-1-81-06-15-2
8	637	158	1.1	C/P	C/P	1.187	1.191	6.889	FP-1-81-06-17-4
9	746	325	0.4	C/P	C/P	1.185	1.192	6.890	FP-1-81-06-15-1
10	749	N/A	N/A	C/P	C/P	1.186	1.192	6.892	FP-1-81-06-12-3
11	949	601	0.0	C/P	C/P	1.175	1.194	6.887	FP-1-81-06-12-2
12	1048	720	0.3	C/P	C/P	1.169	1.191	6.886 +	FP-1-81-06-12-1
13	1266	951	-0.3	C/P	C/P	*	*	**	FP-1-81-06-17-3
14	1394	1076	0.1	C/P	C/P	N/A	N/A	**	FP-1-81-06-17-2
15	1489	1158	0.2	C/P	C/P	*	*	**	FP-1-81-06-17-1

C/P - Complete penetration N/A - Not available * - Not applicable
** - Penetrator broke up; see last table of this Appendix + - Broke in two after sphere was recovered
Note: Exit angles greater than 90° are ricochet angles.

TABLE A11b. Target Effects Data For 15/32 Inch Spheres Impacting 1/2 Inch Aluminum At 0 Degrees

PENETRATOR CHARACTERISTICS

SHAPE - Sphere (Ball Bearing)
MATERIAL - Steel
DIAMETER - 1.191 cm.
MASS - 6.888 g.
HARDNESS - 65 Rc

TARGET CHARACTERISTICS

SHAPE - (7.6 or 10) x 30 cm. Plate
MATERIAL - Aluminum 2024-T351
THICKNESS - 5.080 cm.
HARDNESS - 153 BHN
IMPACT ANGLE - 0°

	HOLE DIAMETERS ENTRANCE Min. (cm)	HOLE DIAMETERS ENTRANCE Max. (cm)	HOLE DIAMETERS EXIT Min. (cm)	HOLE DIAMETERS EXIT Max. (cm)	CRATER WIDTH (cm)	CRATER LENGTH (cm)	GROOVE WIDTH (cm)	GROOVE LENGTH (cm)	REAR SURFACE BULGE (cm)	SHOT IDENTIFICATION
1	1.15	1.15	1.15	1.15	1.15	1.15	*	*	0.07	FP-1-81-06-16-4
2	1.27	1.27	1.27	1.27	1.27	1.27	*	*	0.13	FP-1-81-06-16-3
3	1.27	1.43	1.27	1.43	1.27	1.43	*	*	0.19	FP-1-81-06-16-2
4	1.27	1.43	1.27	1.43	1.27	1.43	*	*	0.22	FP-1-81-06-16-1
5	1.19	1.59	1.19	1.59	1.19	1.59	*	*	0.33	FP-1-81-06-15-4
6	1.59	1.71	1.19	1.19	1.35	1.75	*	*	*	FP-1-81-06-15-3
7	1.71	1.71	1.19	1.19	1.59	1.82	*	*	*	FP-1-81-06-17-4
8	1.59	1.75	1.15	1.39	1.43	1.87	*	*	*	FP-1-81-06-15-2
9	1.59	1.75	1.11	1.11	1.59	1.90	*	*	*	FP-1-81-06-15-1
10	1.67	1.67	1.19	1.19	1.67	1.75	*	*	*	FP-1-81-06-12-3
11	1.60	1.60	1.15	1.15	1.80	2.00	*	*	*	FP-1-81-06-12-2
12	1.60	1.70	1.15	1.15	2.00	2.10	*	*	*	FP-1-81-06-12-1
13	1.75	1.91	1.19	1.19	2.06	2.14	*	*	*	FP-1-81-06-17-3
14	1.91	1.91	1.35	1.35	2.06	2.14	*	*	*	FP-1-81-06-17-2
15	1.91	2.06	1.34	1.35	2.26	2.26	*	*	*	FP-1-81-06-17-1

N/A - Not available * - Not applicable

TABLE A12a. Target Effects Data For 15/32 Inch Spheres Impacting 3 Inch Aluminum At 0 Degrees

PENETRATOR CHARACTERISTICS		TARGET CHARACTERISTICS	
SHAPE	- Sphere (Ball Bearing)	SHAPE	- (7.6 or 10) x 30 cm. Plate
MATERIAL	- Steel	MATERIAL	- Aluminum 24S-T
DIAMETER	- 1.191 cm.	THICKNESS	- 7.620 cm.
MASS	- 6.888 g.	HARDNESS	- 163 BHN
HARDNESS	- 65 Rc	IMPACT ANGLE	- 0°

	STRIKING SPEED (m/s)	EXIT SPEED (m/s)	EXIT ANGLE (deg)	LOS PENETRATION (cm)	PERPENDICULAR PENETRATION (cm)	RECOVERED PENETRATOR MIN. DIA (cm)	RECOVERED PENETRATOR MAX. DIA (cm)	RECOVERED PENETRATOR MASS (g)	SHOT IDENTIFICATION
1	189	40	179.8	0.19	0.19	1.190	1.190	6.888	FP-1-81-08-17-2
2	360	51	180.2	0.39	0.39	1.189	1.190	6.889	FP-1-81-08-17-1
3	371	52	181.0	0.42	0.42	1.189	1.192	6.888	FP-1-81-08-14-4
4	430	55	180.9	0.50	0.50	1.190	1.191	6.888	FP-1-81-08-14-3
5	586	66	180.8	0.81	0.81	1.189	1.191	6.889	FP-1-81-08-14-2
6	722	66	178.6	1.09	1.09	1.185	1.192	6.889	FP-1-81-08-12-3
7	733	66	177.3	1.09	1.09	1.184	1.192	6.889	FP-1-81-08-14-1
8	835	53	180.4	1.30	1.30	1.180	1.193	6.888	FP-1-81-08-12-4
9	908	34	182.1	1.48	1.48	1.178	1.194	6.890	FP-1-81-08-12-1
10	938	0	*	1.17	1.17	N/A	N/A	N/A	FP-1-81-08-17-3
11	992	0	*	1.53	1.53	N/A	N/A	N/A	FP-1-81-08-12-2
12	1361	0	*	2.55	2.55	N/A	N/A	N/A	FP-1-81-08-18-1

C/P - Complete penetration N/A - Not available * - Not applicable
Note: Exit angles greater than 90° are ricochet angles.

TABLE A12b. Target Effects Data For 15/32 Inch Spheres Impacting 3 Inch Aluminum At 0 Degrees

PENETRATOR CHARACTERISTICS		TARGET CHARACTERISTICS	
SHAPE	- Sphere (Ball Bearing)	SHAPE	- (7.6 or 10) x 30 cm. Plate
MATERIAL	- Steel	MATERIAL	- Aluminum 24S-T
DIAMETER	- 1.191 cm.	THICKNESS	- 7.620 cm.
MASS	- 6.888 g.	HARDNESS	- 163 BHN
HARDNESS	- 65 Rc	IMPACT ANGLE	- 0°

	HOLE DIAMETERS				CRATER		GROOVE		REAR SURFACE BULGE	SHOT IDENTIFICATION
	ENTRANCE		EXIT		WIDTH	LENGTH	WIDTH	LENGTH		
	Min. (cm)	Max. (cm)	Min. (cm)	Max. (cm)	(cm)	(cm)	(cm)	(cm)	(cm)	
1	0.93	0.93	0.93	0.93	0.93	0.93	*	*	*	FP-1-81-08-17-2
2	1.19	1.19	1.19	1.19	1.19	1.19	*	*	*	FP-1-81-08-17-1
3	1.22	1.22	1.22	1.22	1.22	1.22	*	*	*	FP-1-81-08-14-4
4	1.31	1.31	1.19	1.19	1.31	1.31	*	*	*	FP-1-81-08-14-3
5	1.49	1.49	1.19	1.19	1.65	1.78	*	*	*	FP-1-81-08-14-2
6	1.53	1.53	1.19	1.19	1.74	1.74	*	*	*	FP-1-81-08-12-3
7	1.53	1.53	1.19	1.19	1.80	1.80	*	*	*	FP-1-81-08-14-1
8	1.50	1.50	1.19	1.19	1.77	1.92	*	*	*	FP-1-81-08-12-4
9	1.66	1.66	1.19	1.19	1.66	1.66	*	*	*	FP-1-81-08-12-1
10	1.60	1.60	*	*	1.82	1.82	*	*	*	FP-1-81-08-17-3
11	1.66	1.66	*	*	1.80	2.00	*	*	*	FP-1-81-08-12-2
12	1.67	1.67	*	*	1.93	2.51	*	*	*	FP-1-81-08-18-1

N/A - Not available * - Not applicable

TABLE A13a. Target Effects Data For 15/32 Inch Spheres Impacting 1/4 Inch Aluminum At 45 Degrees

PENETRATOR CHARACTERISTICS		TARGET CHARACTERISTICS	
SHAPE	- Sphere (Ball Bearing)	SHAPE	- (7.6 or 10) x 30 cm. Plate
MATERIAL	- Steel	MATERIAL	- Aluminum 2024-T351
DIAMETER	- 1.191 cm.	THICKNESS	- 0.635 cm.
MASS	- 6.888 g.	HARDNESS	- 143 BHN
HARDNESS	- 65 Rc	IMPACT ANGLE	- 45°

	STRIKING SPEED (m/s)	EXIT SPEED (m/s)	EXIT ANGLE (deg)	LOS PENETRATION (cm)	PERPENDICULAR PENETRATION (cm)	RECOVERED PENETRATOR MIN. DIA (cm)	RECOVERED PENETRATOR MAX. DIA (cm)	RECOVERED PENETRATOR MASS (g)	SHOT IDENTIFICATION
1	155	80	109.7	0.37	0.14	1.189	1.190	6.888	FP-1-81-08-31-6
2	190	90	110.4	0.50	0.18	1.190	1.191	6.888	FP-1-81-09-01-1
3	249	103	114.3	0.61	0.27	1.189	1.190	6.888	FP-1-81-08-31-1
4	299	100	113.2	0.58	0.34	1.190	1.190	6.887	FP-1-81-08-31-3
5	332	98	116.2	0.74	0.40	1.190	1.190	6.888	FP-1-81-08-31-2
6	358	92	118.6	0.83	0.41	1.189	1.192	6.888	FP-1-81-08-31-4
7	407	76	126.5	1.01	0.52	1.189	1.190	6.887	FP-1-81-09-01-2
8	408	65	131.1	1.02	0.51	1.189	1.190	6.887	FP-1-81-08-31-5
9	444	33	155.2	1.39	0.67	1.190	1.190	6.887	FP-1-81-09-04-2
10	451	13	182.0	1.23	0.59	1.189	1.190	6.887	FP-1-81-09-01-3
11	455	28	150.7	1.48	0.62	1.190	1.190	6.888	FP-1-81-09-04-3
12	460	15	210.2	1.48	0.49	1.189	1.190	6.888	FP-1-81-08-28-2
13	481	18	181.9	1.48	1.05	1.189	1.190	6.886	FP-1-81-09-01-4
14	497	20	177.1	N/A	N/A	1.189	1.191	6.887	FP-1-81-09-01-6
15	497	16	185.5	N/A	N/A	1.189	1.190	6.887	FP-1-81-09-03-5
16	502	26	3.9	C/P	C/P	1.190	1.190	6.886	FP-1-81-09-03-6
17	516	85	-0.5	C/P	C/P	1.189	1.190	6.886	FP-1-81-09-03-4
18	519	88	-4.5	C/P	C/P	1.190	1.192	6.888	FP-1-81-09-03-1
19	522	89	7.8	C/P	C/P	1.190	1.191	6.887	FP-1-81-09-03-2

C/P - Complete penetration N/A - Not available * - Not applicable
** - Penetrator broke up; see last table of this Appendix
Note: Exit angles greater than 90° are ricochet angles.

TABLE A13a. (Continued)

	STRIKING SPEED (m/s)	EXIT SPEED (m/s)	EXIT ANGLE (deg)	LOS PENETRATION (cm)	PERPENDICULAR PENETRATION (cm)	RECOVERED PENETRATOR MIN. DIA (cm)	MAX. DIA (cm)	MASS (g)	SHOT IDENTIFICATION
20	530	115	4.3	C/P	C/P	1.190	1.190	6.888	FP-1-81-09-03-3
21	616	294	34.1	C/P	C/P	1.189	1.190	6.887	FP-1-81-08-28-1
22	708	419	38.4	C/P	C/P	1.190	1.192	6.888	FP-1-81-09-02-5
23	794	530	41.6	C/P	C/P	1.188	1.190	6.888	FP-1-81-09-02-4
24	930	687	43.5	C/P	C/P	1.184	1.191	6.887	FP-1-81-09-02-3
25	1044	810	44.2	C/P	C/P	1.183	1.191	6.887	FP-1-81-09-02-2
26	1239	1016	45.1	C/P	C/P	*	*	**	FP-1-81-09-02-1
27	1275	1051	45.0	C/P	C/P	*	*	**	FP-1-81-09-04-1

C/P - Complete penetration N/A - Not available * - Not applicable
** - Penetrator broke up; see last table of this Appendix
Note: Exit angles greater than 90° are ricochet angles.

TABLE A13b. Target Effects Data For 15/32 Inch Spheres Impacting 1/4 Inch Aluminum At 45 Degrees

PENETRATOR CHARACTERISTICS		TARGET CHARACTERISTICS	
SHAPE	- Sphere (Ball Bearing)	SHAPE	- (7.6 or 10) x 30 cm. Plate
MATERIAL	- Steel	MATERIAL	- Aluminum 2024-T351
DIAMETER	- 1.191 cm.	THICKNESS	- 0.635 cm.
MASS	- 6.888 g.	HARDNESS	- 143 BHN
HARDNESS	- 65 Rc	IMPACT ANGLE	- 45°

	HOLE DIAMETERS ENTRANCE Min. (cm)	HOLE DIAMETERS ENTRANCE Max. (cm)	HOLE DIAMETERS EXIT Min. (cm)	HOLE DIAMETERS EXIT Max. (cm)	CRATER WIDTH (cm)	CRATER LENGTH (cm)	GROOVE WIDTH (cm)	GROOVE LENGTH (cm)	REAR SURFACE BULGE (cm)	SHOT IDENTIFICATION
1	*	*	*	*	F 0.62	F 0.90	0.62	0.90	0.02	FP-1-81-08-31-6
2	*	*	*	*	F 0.70	F 1.06	0.70	1.06	0.05	FP-1-81-09-01-1
3	*	*	*	*	F 0.80	F 1.35	0.80	1.35	0.11	FP-1-81-08-31-3
4	*	*	*	*	F 1.00	F 1.53	1.00	1.53	0.15	FP-1-81-08-31-3
5	*	*	*	*	F 0.99	F 1.60	0.99	1.60	0.17	FP-1-81-08-31-2
6	*	*	*	*	F 1.08	F 1.70	1.08	1.70	0.22	FP-1-81-08-31-4
7	*	1.00	*	1.10	F 1.14	F 1.93	1.14	1.93	0.30	FP-1-81-09-01-2
8	*	1.00	*	1.10	F 1.13	F 1.87	1.13	1.87	0.29	FP-1-81-08-31-5
9	*	1.03	*	1.10	F 1.16	F 2.05	1.16	2.05	0.47	FP-1-81-09-04-2
10	*	1.06	*	1.20	F 1.17	F 2.02	1.17	2.02	0.51	FP-1-81-09-01-3
11	*	1.10	*	1.15	F 1.38	F 2.10	1.26	2.10	0.49	FP-1-81-09-04-3
12	*	0.97	*	1.06	F 1.35	F 2.07	1.16	2.07	*	FP-1-81-08-28-2
					R 0.87	R 1.35				
13	*	1.00	*	1.19	F 1.44	F 2.19	1.19	2.19	0.76	FP-1-81-09-01-4
14	*	1.08	*	1.19	F 1.39	F 2.20	1.16	2.14	*	FP-1-81-09-01-6
					R 0.93	R 1.50				
15	*	1.08	*	1.11	F 1.26	F 2.19	1.26	2.19	*	FP-1-81-09-03-5
					R 1.00	R 2.02				

F - the entrance side of the target plate; R - the exit side of the target plate
N/A - Not available * - Not applicable

TABLE A13b. (Continued)

	HOLE DIAMETERS				CRATER		GROOVE		REAR	SHOT
	ENTRANCE		EXIT		WIDTH	LENGTH	WIDTH	LENGTH	SURFACE	IDENTIFICATION
	Min.	Max.	Min.	Max.					BULGE	
	(cm)	(cm)	(cm)	(cm)	(cm)	(cm)	(cm)	(cm)	(cm)	
16	*	1.05	*	1.05	F 1.34	F 2.12	*	*	*	FP-1-81-09-03-6
					R 1.40	R 2.10				
17	*	1.00	*	1.11	F 1.41	F 2.15	*	*	*	FP-1-81-09-03-4
					R 1.75	R 1.95				
18	*	1.14	*	1.14	F 1.48	F 2.32	*	*	*	FP-1-81-09-03-1
					R 1.55	R 1.91				
19	*	1.10	*	1.10	F 1.36	F 2.20	*	*	*	FP-1-81-09-03-2
					R 1.55	R 1.91				
20	*	1.16	*	1.16	F 1.34	F 2.16	*	*	*	FP-1-81-09-03-3
					R 1.70	R 1.93				
21	*	1.08	*	1.15	F 1.30	F 2.10	*	*	*	FP-1-81-08-28-1
					R 1.94	R 2.40				
22	*	1.08	*	1.10	F 1.40	F 2.29	*	*	*	FP-1-81-09-02-5
					R 1.70	R 2.38				
23	*	1.09	*	1.14	F 1.53	F 2.33	*	*	*	FP-1-81-09-02-4
					R 1.70	R 2.41				
24	*	1.12	*	1.05	F 1.44	F 2.38	*	*	*	FP-1-81-09-02-3
					R 1.72	R 2.42				

F - the entrance side of the target plate; R - the exit side of the target plate
N/A - Not available * - Not applicable

TABLE A13b. (Continued)

	HOLE DIAMETERS ENTRANCE Min. (cm)	HOLE DIAMETERS ENTRANCE Max. (cm)	HOLE DIAMETERS EXIT Min. (cm)	HOLE DIAMETERS EXIT Max. (cm)	CRATER WIDTH (cm)	CRATER LENGTH (cm)	GROOVE WIDTH (cm)	GROOVE LENGTH (cm)	REAR SURFACE BULGE (cm)	SHOT IDENTIFICATION
25	*	1.06	*	1.19	F 1.65	F 2.39	*	*	*	FP-1-81-09-02-2
					R 1.73	R 2.44				
26	*	1.32	*	1.19	F 1.60	F 2.37	*	*	*	FP-1-81-09-02-1
					R 1.72	R 2.50				
27	*	1.09	*	1.16	F 1.87	F 2.41	*	*	*	FP-1-81-09-04-1
					R 1.80	R 2.53				

F - the entrance side of the target plate; R - the exit side of the target plate
N/A - Not available * - Not applicable

TABLE A14a. Target Effects Data For 15/32 Inch Spheres Impacting 1/2 Inch Aluminum At 45 Degrees

PENETRATOR CHARACTERISTICS		TARGET CHARACTERISTICS	
SHAPE	- Sphere (Ball Bearing)	SHAPE	- (7.6 or 10) x 30 cm. Plate
MATERIAL	- Steel	MATERIAL	- Aluminum 2024-T351
DIAMETER	- 1.191 cm.	THICKNESS	- 5.080 cm.
MASS	- 6.888 g.	HARDNESS	- 153 BHN
HARDNESS	- 65 Rc	IMPACT ANGLE	- 45°

	STRIKING SPEED (m/s)	EXIT SPEED (m/s)	EXIT ANGLE (deg)	LOS PENETRATION (cm)	PERPENDICULAR PENETRATION (cm)	RECOVERED PENETRATOR MIN. DIA (cm)	MAX. DIA (cm)	MASS (g)	SHOT IDENTIFICATION
1	174	99	117.5	0.43	0.14	1.189	1.190	6.886	FP-1-81-08-26-5
2	229	124	111.4	0.50	0.19	1.189	1.191	6.885	FP-1-81-08-26-4
3	303	153	116.8	0.75	0.25	1.189	1.190	6.886	FP-1-81-08-26-3
4	361	N/A	N/A	0.80	0.29	1.190	1.190	6.886	FP-1-81-08-27-1
5	366	157	124.1	0.84	0.30	1.189	1.190	6.886	FP-1-81-08-27-2
6	421	166	128.2	0.92	0.41	1.189	1.190	6.886	FP-1-81-08-26-2
7	482	131	131.3	1.09	0.44	1.190	1.191	6.886	FP-1-81-08-27-4
8	482	143	126.2	1.09	0.44	1.190	1.190	6.887	FP-1-81-08-27-8
9	494	144	139.3	1.07	0.51	1.189	1.190	6.888	FP-1-81-08-26-1
10	587	102	146.6	1.34	0.62	1.190	1.192	6.887	FP-1-81-08-27-3
11	644	64	181.0	1.67	0.74	1.189	1.190	6.887	FP-1-81-08-27-7
12	648	72	137.8	1.57	0.73	1.190	1.190	6.887	FP-1-81-08-27-5
13	694	38	202.5	2.05	0.87	1.190	1.190	6.888	FP-1-81-08-27-6
14	750	17	216.3	2.28	1.08	1.189	1.192	6.888	FP-1-81-08-25-6
15	777	0	*	1.55	N/A	1.189	1.192	6.888+	FP-1-81-08-25-7
16	790	75	-1.7	C/P	C/P	1.188	1.191	6.888	FP-1-81-08-25-5
17	814	141	7.3	C/P	C/P	1.188	1.192	6.899++	FP-1-81-08-25-4

C/P - Complete penetration N/A - Not available * - Not applicable + - Ball embeded but extracted
** - Penetrator broke up; see last table of this Appendix ++ - Added mass due to stuck aluminum
Note: Exit angles greater than 90° are ricochet angles.

TABLE A14a. (Continued)

	STRIKING SPEED (m/s)	EXIT SPEED (m/s)	EXIT ANGLE (deg)	LOS PENETRATION (cm)	PERPENDICULAR PENETRATION (cm)	RECOVERED PENETRATOR MIN. DIA (cm)	RECOVERED PENETRATOR MAX. DIA (cm)	RECOVERED PENETRATOR MASS (g)	SHOT IDENTIFICATION
18	956	374	33.3	C/P	C/P	1.185	1.193	6.888	FP-1-81-08-24-1
19	1079	558	39.3	C/P	C/P	1.179	1.192	6.889	FP-1-81-08-24-3
20	1083	N/A	N/A	C/P	C/P	1.180	1.194	6.889	FP-1-81-08-24-2
21	1197	720	42.8	C/P	C/P	1.188	1.196	6.888	FP-1-81-08-24-4
22	1323	855	43.9	C/P	C/P	*	*	**	FP-1-81-08-25-3
23	416	952	44.4	C/P	C/P	*	*	**	FP-1-81-08-25-2
24	1477	1013	43.8	C/P	C/P	*	*	**	FP-1-81-08-25-1

C/P - Complete penetration N/A - Not available * - Not applicable
** - Penetrator broke up; see last table of this Appendix
Note: Exit angles greater than 90° are ricochet angles.

TABLE A14b. Target Effects Data For 15/32 Inch Spheres Impacting 1/2 Inch Aluminum At 45 Degrees

PENETRATOR CHARACTERISTICS

SHAPE - Sphere (Ball Bearing)
MATERIAL - Steel
DIAMETER - 1.191 cm.
MASS - 6.888 g.
HARDNESS - 65 Rc

TARGET CHARACTERISTICS

SHAPE - (7.6 or 10) x 30 cm. Plate
MATERIAL - Aluminum 2024-T351
THICKNESS - 5.080 cm.
HARDNESS - 153 BHN
IMPACT ANGLE - 45°

	HOLE DIAMETERS				CRATER		GROOVE		REAR	SHOT
	ENTRANCE		EXIT		WIDTH	LENGTH	WIDTH	LENGTH	SURFACE BULGE	IDENTIFICATION
	Min. (cm)	Max. (cm)	Min. (cm)	Max. (cm)	(cm)	(cm)	(cm)	(cm)	(cm)	
1	*	0.77	*	0.77	F 0.77	F 1.02	0.77	1.02	0.00	FP-1-81-08-26-5
2	*	0.90	*	0.90	F 0.90	F 1.25	0.90	1.25	0.00	FP-1-81-08-26-4
3	*	1.00	*	1.00	F 1.24	F 1.41	1.00	1.41	0.01	FP-1-81-08-26-3
4	*	1.10	*	0.90	F 1.29	F 1.80	1.08	1.80	0.01	FP-1-81-08-27-1
5	*	1.02	*	1.00	F 1.42	F 1.65	1.09	1.65	0.01	FP-1-81-08-27-2
6	*	1.19	*	1.04	F 1.42	F 1.90	1.24	1.90	0.04	FP-1-81-08-26-2
7	*	1.11	*	1.11	F 1.48	F 2.22	1.14	2.22	0.10	FP-1-81-08-27-4
8	*	1.19	*	1.19	F 1.41	F 2.14	1.19	2.14	0.09	FP-1-81-08-27-8
9	*	1.18	*	1.19	F 1.50	F 2.08	1.19	2.08	0.04	FP-1-81-08-26-1
10	*	1.14	*	1.19	F 1.66	F 2.40	1.24	2.40	0.14	FP-1-81-08-27-3
11	*	1.16	*	1.19	F 1.78	F 2.37	1.24	2.28	0.20	FP-1-81-08-27-7
12	*	1.14	*	1.23	F 1.56	F 2.67	1.19	2.67	0.21	FP-1-81-08-27-5
13	*	1.10	*	1.19	F 1.62	F 2.59	1.20	2.36	0.29	FP-1-81-08-27-6
14	*	1.13	*	1.16	F 1.79	F 2.70	1.33	2.50	0.46	FP-1-81-08-25-6
15	*	1.16	*	1.16	F 1.77 R 1.68	F 2.30 R 2.14	1.24	2.54	N/A	FP-1-81-08-25-7
16	*	1.20	*	1.14	F 1.86 R 2.16	F 2.89 R 2.37	*	*	*	FP-1-81-08-25-5

F - the entrance side of the target plate; R - the exit side of the target plate
N/A - Not available * - Not applicable

TABLE A14b. (Continued)

	HOLE DIAMETERS				CRATER		GROOVE		REAR	SHOT
	ENTRANCE		EXIT		WIDTH	LENGTH	WIDTH	LENGTH	SURFACE BULGE	IDENTIFICATION
	Min. (cm)	Max. (cm)	Min. (cm)	Max. (cm)	(cm)	(cm)	(cm)	(cm)	(cm)	
17	*	1.21	*	1.11	F 1.96 R 2.09	F 2.83 R 2.46	*	*	*	FP-1-81-08-25-4
18	*	1.10	*	1.10	F 2.01 R 1.94	F 2.78 R 2.77	*	*	*	FP-1-81-08-24-1
19	*	1.14	*	1.12	F 2.18 R 1.97	F 2.55 R 2.78	*	*	*	FP-1-81-08-24-3
20	*	1.20	*	1.13	F 2.12 R 2.04	F 2.66 R 2.84	*	*	*	FP-1-81-08-24-2
21	*	1.10	*	1.10	F 2.00 R 1.99	F 2.89 R 3.18	*	*	*	FP-1-81-08-24-4
22	*	1.10	*	1.16	F 2.31 R 2.01	F 2.73 R 3.23	*	*	*	FP-1-81-08-25-3
23	*	1.05	*	1.06	F 2.23 R 2.09	F 2.90 R 3.32	*	*	*	FP-1-81-08-25-2
24	*	1.10	*	1.15	F 2.13 R 2.19	F 2.89 R 3.40	*	*	*	FP-1-81-08-25-1

F - the entrance side of the target plate; R - the exit side of the target plate
N/A - Not available * - Not applicable

TABLE A15a. Target Effects Data For 15/32 Inch Spheres Impacting 2 Inch Aluminum At 45 Degrees

PENETRATOR CHARACTERISTICS		TARGET CHARACTERISTICS	
SHAPE	- Sphere (Ball Bearing)	SHAPE	- (7.6 or 10) x 30 cm. Plate
MATERIAL	- Steel	MATERIAL	- Aluminum 24S-T
DIAMETER	- 1.191 cm.	THICKNESS	- 5.080 cm.
MASS	- 6.888 g.	HARDNESS	- 163 BHN
HARDNESS	- 65 Rc	IMPACT ANGLE	- 45°

	STRIKING SPEED (m/s)	EXIT SPEED (m/s)	EXIT ANGLE (deg)	LOS PENETRATION (cm)	PERPENDICULAR PENETRATION (cm)	RECOVERED PENETRATOR MIN. DIA (cm)	RECOVERED PENETRATOR MAX. DIA (cm)	RECOVERED PENETRATOR MASS (g)	SHOT IDENTIFICATION
1	237	137	115.3	0.47	0.17	1.190	1.190	6.888	FP-1-81-08-05-1
2	373	177	122.9	0.67	0.34	1.190	1.191	6.889	FP-1-81-08-10-3
3	412	186	124.7	0.86	0.32	1.190	1.190	6.889	FP-1-81-08-05-2
4	508	187	135.3	0.97	0.45	1.190	1.190	6.889	FP-1-81-08-05-3
5	543	171	128.7	1.14	0.56	1.190	1.192	6.890	FP-1-81-08-04-4
6	580	170	130.7	1.34	0.54	1.190	1.191	6.888	FP-1-81-08-10-2
7	607	175	129.9	1.22	0.57	1.190	1.190	6.889	FP-1-81-08-05-4
8	697	182	133.4	1.55	0.71	1.189	1.191	6.889	FP-1-81-08-04-5
9	810	168	141.9	1.72	0.87	1.190	1.191	6.889	FP-1-81-08-04-2
10	857	132	139.3	1.83	0.91	1.186	1.192	6.890	FP-1-81-08-04-1
11	1033	117	171.7	2.47	1.32	1.188	1.193	6.889	FP-1-81-07-27-1
12	1039	109	165.0	2.50	1.32	1.181	1.193	6.891	FP-1-81-07-27-2
13	1110	N/A	N/A	2.70	1.49	1.181	1.200	6.890	FP-1-81-07-27-4
14	1114	71	157.8	2.82	1.50	1.187	1.196	6.891	FP-1-81-08-10-1
15	1118	28	218.1	2.59	1.47	1.187	1.194	6.889	FP-1-81-07-27-3
16	1131	83	183.1	2.71	1.57	1.176	1.196	6.891	FP-1-81-08-05-5
17	1211	38	192.1	3.01	1.67	1.173	1.202	6.889	FP-1-81-07-28-1
18	1216	56	181.6	2.97	1.71	1.175	1.196	6.890	FP-1-81-07-28-2
19	1264	41	203.4	3.34	1.77	1.170	1.199	6.890	FP-1-81-07-28-3

C/P - Complete penetration N/A - Not available * - Not applicable
** - Penetrator broke up; see last table of this Appendix
Note: Exit angles greater than 90° are ricochet angles.

TABLE A15a. (Continued)

	STRIKING SPEED (m/s)	EXIT SPEED (m/s)	EXIT ANGLE (deg)	LOS PENETRATION (cm)	PERPENDICULAR PENETRATION (cm)	RECOVERED PENETRATOR MIN. DIA (cm)	RECOVERED PENETRATOR MAX. DIA (cm)	RECOVERED PENETRATOR MASS (g)	SHOT IDENTIFICATION
20	1339	30	211.5	3.47	1.96	1.175	1.208	6.890	FP-1-81-08-03-3
21	1374	0	*	3.53	1.98	1.165	1.203	6.890	FP-1-81-08-03-1
22	1440	0	*	4.14	2.05	N/A	N/A	N/A	FP-1-81-08-03-4
23	1542	49	176.7	2.47	1.67	*	*	**	FP-1-81-07-24-3

C/P - Complete penetration N/A - Not available * - Not applicable
** - Penetrator broke up; see last table of this Appendix
Note: Exit angles greater than 90° are ricochet angles.

TABLE A15b. Target Effects Data For 15/32 Inch Spheres Impacting 2 Inch Aluminum At 45 Degrees

PENETRATOR CHARACTERISTICS		TARGET CHARACTERISTICS	
SHAPE	- Sphere (Ball Bearing)	SHAPE	- (7.6 or 10) x 30 cm. Plate
MATERIAL	- Steel	MATERIAL	- Aluminum 24S-T
DIAMETER	- 1.191 cm.	THICKNESS	- 5.080 cm.
MASS	- 6.888 g.	HARDNESS	- 163 BHN
HARDNESS	- 65 Rc	IMPACT ANGLE	- 45°

	HOLE DIAMETERS				CRATER		GROOVE		REAR SURFACE BULGE	SHOT IDENTIFICATION
	ENTRANCE		EXIT		WIDTH	LENGTH	WIDTH	LENGTH		
	Min. (cm)	Max. (cm)	Min. (cm)	Max. (cm)	(cm)	(cm)	(cm)	(cm)	(cm)	
1	*	0.92	*	0.92	0.92	1.23	0.92	1.23	*	FP-1-81-08-05-1
2	*	1.10	*	1.10	1.10	1.73	1.10	1.73	*	FP-1-81-08-10-3
3	*	1.17	*	1.04	1.36	1.90	1.11	1.68	*	FP-1-81-08-05-2
4	*	1.06	*	1.06	1.54	2.20	1.16	2.10	*	FP-1-81-08-05-3
5	*	1.12	*	1.05	1.74	2.55	1.20	2.10	*	FP-1-81-08-04-4
6	*	1.21	*	1.21	1.58	2.49	1.46	2.49	*	FP-1-81-08-10-2
7	*	1.10	*	1.12	1.81	2.71	1.28	2.26	*	FP-1-81-08-05-4
8	*	1.14	*	1.32	1.96	2.89	1.37	2.56	*	FP-1-81-08-04-3
9	*	1.14	*	1.14	2.20	3.13	1.44	2.74	*	FP-1-81-08-04-2
10	*	1.00	*	1.66	2.56	3.46	1.78	3.00	*	FP-1-81-08-04-1
11	*	1.16	*	1.56	2.36	3.77	1.30	3.01	*	FP-1-81-07-27-1
12	*	1.08	*	1.52	2.77	3.84	1.60	3.85	*	FP-1-81-07-27-2
13	*	1.13	*	1.59	2.98	4.08	1.80	3.37	*	FP-1-81-07-27-4
14	*	1.33	*	1.54	3.38	4.30	1.83	3.50	*	FP-1-81-08-10-1
15	*	1.34	*	1.60	2.19	3.53	1.60	3.03	*	FP-1-81-07-27-3
16	*	1.29	*	1.60	2.91	3.90	1.64	3.26	*	FP-1-81-08-05-5
17	*	1.14	*	1.55	3.19	4.42	1.63	2.50	*	FP-1-81-07-28-1
18	*	1.08	*	1.59	2.60	4.73	1.62	3.55	*	FP-1-81-07-28-2
19	*	1.21	*	1.47	3.90	4.18	1.62	3.50	*	FP-1-81-07-28-3

N/A - Not available * - Not applicable

TABLE A15b. (Continued)

	HOLE DIAMETERS				CRATER		GROOVE		REAR SURFACE BULGE	SHOT IDENTIFICATION
	ENTRANCE		EXIT		WIDTH	LENGTH	WIDTH	LENGTH		
	Min. (cm)	Max. (cm)	Min. (cm)	Max. (cm)	(cm)	(cm)	(cm)	(cm)	(cm)	
20	*	1.19	*	1.60	4.00	4.74	1.66	3.60	*	FP-1-81-08-03-3
21	*	1.29	*	*	N/A	N/A	1.69	3.50	*	FP-1-81-08-03-1
22	*	1.38	*	*	3.76	3.75	1.60	N/A	*	FP-1-81-08-03-4
23	*	1.14	*	1.73	4.47	5.27	1.65	3.85	*	FP-1-81-07-24-3

N/A - Not available * - Not applicable

TABLE A16a. Target Effects Data For 15/32 Inch Spheres Impacting 1/4 Inch Aluminum At 60 Degrees

PENETRATOR CHARACTERISTICS		TARGET CHARACTERISTICS	
SHAPE	- Sphere (Ball Bearing)	SHAPE	- (7.6 or 10) x 30 cm. Plate
MATERIAL	- Steel	MATERIAL	- Aluminum 2024-T351
DIAMETER	- 1.191 cm.	THICKNESS	- 0.635 cm.
MASS	- 6.888 g.	HARDNESS	- 143 BHN
HARDNESS	- 65 Rc	IMPACT ANGLE	- 60°

	STRIKING SPEED (m/s)	EXIT SPEED (m/s)	EXIT ANGLE (deg)	LOS PENETRATION (cm)	PERPENDICULAR PENETRATION (cm)	RECOVERED PENETRATOR MIN. DIA (cm)	RECOVERED PENETRATOR MAX. DIA (cm)	RECOVERED PENETRATOR MASS (g)	SHOT IDENTIFICATION
1	133	104	102.4	0.32	0.06	1.190	1.192	6.886	FP-1-81-10-29-1
2	249	175	102.3	0.52	0.17	1.190	1.191	6.886	FP-1-81-10-28-2
3	269	184	104.1	0.51	0.18	1.190	1.192	6.886	FP-1-81-10-28-1
4	315	N/A	N/A	0.88	0.24	N/A	N/A	N/A	FP-1-81-10-15-4
5	333	216	104.5	0.90	0.28	1.190	1.191	6.885	FP-1-81-10-22-4
6	388	210	110.3	0.89	0.40	1.190	1.191	6.885	FP-1-81-10-22-2
7	466	210	111.5	1.30	0.53	1.191	1.191	6.885	FP-1-81-10-22-3
8	591	199	114.8	2.18	0.78	1.190	1.191	6.885	FP-1-81-10-22-1
9	632	158	119.7	2.12	0.635	1.190	1.191	6.885	FP-1-81-10-23-1
10	673	67	135.7	2.85	0.635	1.190	1.191	6.886	FP-1-81-10-23-2
11	682	44	156.1	2.88	0.635	1.190	1.191	6.886	FP-1-81-10-14-2
12	686	44	160.6	3.00	0.635	1.190	1.191	6.885	FP-1-81-10-23-3
13	695	17	162.1	3.10	0.635	1.190	1.191	6.885	FP-1-81-10-21-1
14	697	N/A	N/A	C/P	C/P	1.191	1.191	6.886	FP-1-81-10-14-1
15	711	67	-6.2	C/P	C/P	1.191	1.192	6.885	FP-1-81-10-23-4
16	719	138	25.1	C/P	C/P	N/A	N/A	N/A	FP-1-81-10-21-2
17	746	N/A	N/A	C/P	C/P	1.190	1.191	6.886	FP-1-81-10-20-2
18	774	279	46.6	C/P	C/P	1.190	1.191	6.886	FP-1-81-10-20-3
19	816	342	49.6	C/P	C/P	1.190	1.191	6.886	FP-1-81-10-15-3

C/P - Complete penetration N/A - Not available * - Not applicable
Note: Exit angles greater than 90° are ricochet angles.

TABLE A16a. (Continued)

	STRIKING SPEED (m/s)	EXIT SPEED (m/s)	EXIT ANGLE (deg)	LOS PENETRATION (cm)	PERPENDICULAR PENETRATION (cm)	RECOVERED PENETRATOR MIN. DIA (cm)	RECOVERED PENETRATOR MAX. DIA (cm)	RECOVERED PENETRATOR MASS (g)	SHOT IDENTIFICATION
20	818	N/A	N/A	C/P	C/P	1.190	1.192	6.886	FP-1-81-10-15-2
21	859	N/A	N/A	C/P	C/P	1.190	1.192	6.885	FP-1-81-10-15-1
22	931	522	55.2	C/P	C/P	1.190	1.191	6.885	FP-1-81-10-16-1
23	1095	727	58.1	C/P	C/P	1.190	1.192	6.885	FP-1-81-10-16-2
24	1299	952	59.5	C/P	C/P	1.188	1.192	6.886	FP-1-81-10-19-1
25	1417	1069	60.1	C/P	C/P	1.191	1.194	6.885	FP-1-81-10-20-1

C/P - Complete penetration N/A - Not available * - Not applicable
Note: Exit angles greater than 90° are ricochet angles.

TABLE A16b. Target Effects Data For 15/32 Inch Spheres Impacting 1/4 Inch Aluminum At 60 Degrees

PENETRATOR CHARACTERISTICS

SHAPE	- Sphere (Ball Bearing)
MATERIAL	- Steel
DIAMETER	- 1.191 cm.
MASS	- 6.888 g.
HARDNESS	- 65 Rc

TARGET CHARACTERISTICS

SHAPE	- (7.6 or 10) x 30 cm. Plate
MATERIAL	- Aluminum 2024-T351
THICKNESS	- 0.635 cm.
HARDNESS	- 143 BHN
IMPACT ANGLE	- 60°

	HOLE DIAMETERS				CRATER		GROOVE		REAR	SHOT
	ENTRANCE		EXIT		WIDTH	LENGTH	WIDTH	LENGTH	SURFACE BULGE	IDENTIFICATION
	Min. (cm)	Max. (cm)	Min. (cm)	Max. (cm)	(cm)	(cm)	(cm)	(cm)	(cm)	
1	*	*	*	*	F 0.53	F 0.82	0.53	0.82	0.04	FP-1-81-10-29-1
2	*	*	*	*	F 0.75	F 1.33	0.75	1.33	0.07	FP-1-81-10-28-2
3	*	*	*	*	F 0.75	F 1.45	0.75	1.45	0.10	FP-1-81-10-28-1
4	*	0.87	*	0.87	F 0.87	F 1.76	0.87	1.76	0.12	FP-1-81-10-15-4
5	*	0.90	*	0.90	F 0.90	F 1.81	0.90	1.81	0.13	FP-1-81-10-22-4
6	*	0.90	*	0.88	F 0.97	F 2.02	0.97	2.02	0.19	FP-1-81-10-22-2
7	*	1.05	*	1.05	F 1.13	F 2.44	1.13	2.44	0.27	FP-1-81-10-22-3
8	*	0.93	*	1.08	F 1.27	F 3.46	1.18	3.46	0.50	FP-1-81-10-22-1
9	*	0.98	*	1.17	F 1.29 R 1.06	F 3.70 R 2.82	1.15	3.70	*	FP-1-81-10-23-1
10		1.06	*	1.19	F 1.41 R 1.87	F 3.88 R 3.13	1.21	3.88	*	FP-1-81-10-23-2
11	*	1.02	*	1.16	F 1.43 R 1.49	F 3.82 R 3.10	1.20	3.78	*	FP-1-81-10-14-2
12	*	0.93	*	1.24	F 1.46 R 1.50	F 3.80 R 3.13	1.18	3.80	*	FP-1-81-10-23-3
13	*	0.98	*	1.18	F 1.37 R 1.53	F 3.95 R 3.43	1.19	3.78	*	FP-1-81-10-21-1

F - the entrance side of the target plate; R - the exit side of the target plate
N/A - Not available * - Not applicable

TABLE A16b. (Continued)

	HOLE DIAMETERS ENTRANCE Min. (cm)	Max. (cm)	EXIT Min. (cm)	Max. (cm)	CRATER WIDTH (cm)	LENGTH (cm)	GROOVE WIDTH (cm)	LENGTH (cm)	REAR SURFACE BULGE (cm)	SHOT IDENTIFICATION
14	*	1.01	*	1.11	F 1.34 R 1.88	F 3.83 R 3.29	1.16	3.73	*	FP-1-81-10-14-1
15	*	1.04	*	1.16	F 1.44 R 1.83	F 3.79 R 3.48	1.27	3.75	*	FP-1-81-10-23-4
16	*	1.11	*	1.13	F 1.45 R 1.97	F 3.73 R 3.33	1.14	3.73	*	FP-1-81-10-21-2
17	*	1.02	*	1.17	F 1.38 R 1.82	F 3.76 R 3.56	1.19	3.52	*	FP-1-81-10-20-2
18	*	1.07	*	1.10	F 1.43 R 1.77	F 3.85 R 3.46	1.17	3.51	*	FP-1-81-10-20-3
19	*	1.10	*	1.12	F 1.52 R 1.73	F 3.78 R 3.52	1.30	3.50	*	FP-1-81-10-15-3
20	*	1.09	*	1.15	F 1.53 R 1.70	F 3.77 R 3.60	1.21	3.50	*	FP-1-81-10-15-2
21	*	1.01	*	1.14	F 1.64 R 1.73	F 3.71 R 3.63	1.23	3.50	*	FP-1-81-10-15-1
22	*	1.18	*	1.12	F 1.59 R 1.69	F 3.76 R 3.52	1.15	3.30	*	FP-1-81-10-16-1
23	*	1.08	*	1.16	F 1.72 R 1.76	F 3.52 R 3.73	1.19	3.21	*	FP-1-81-10-16-2
24	*	1.07	*	1.13	F 1.85 R 1.79	F 3.48 R 3.69	1.30	3.34	*	FP-1-81-10-19-1
25	*	1.04	*	1.10	F 1.91 R 1.86	F 3.64 R 3.74	1.25	3.36	*	FP-1-81-10-20-1

F - the entrance side of the target plate; R - the exit side of the target plate
N/A - Not available * - Not applicable

TABLE A17a. Target Effects Data For 15/32 Inch Spheres Impacting 1/2 Inch Aluminum At 60 Degrees

PENETRATOR CHARACTERISTICS		TARGET CHARACTERISTICS	
SHAPE	- Sphere (Ball Bearing)	SHAPE	- (7.6 or 10) x 30 cm. Plate
MATERIAL	- Steel	MATERIAL	- Aluminum 2024-T351
DIAMETER	- 1.191 cm.	THICKNESS	- 5.080 cm.
MASS	- 6.888 g.	HARDNESS	- 153 BHN
HARDNESS	- 65 Rc	IMPACT ANGLE	- 60°

	STRIKING SPEED (m/s)	EXIT SPEED (m/s)	EXIT ANGLE (deg)	LOS PENETRATION (cm)	PERPENDICULAR PENETRATION (cm)	RECOVERED PENETRATOR MIN. DIA (cm)	RECOVERED PENETRATOR MAX. DIA (cm)	RECOVERED PENETRATOR MASS (g)	SHOT IDENTIFICATION
1	109	86	109.8	0.35	0.03	1.190	1.191	6.886	FP-1-81-10-29-4
2	124	98	110.1	0.38	0.05	1.190	1.192	6.886	FP-1-81-10-30-1
3	138	N/A	N/A	0.41	0.04	1.189	1.190	6.885	FP-1-81-09-28-3
4	190	144	109.5	0.48	0.08	1.190	1.191	6.885	FP-1-81-10-29-3
5	292	202	108.0	0.72	0.11	1.190	1.192	6.886	FP-1-81-10-29-2
6	387	255	111.2	0.83	0.19	1.189	1.190	6.885	FP-1-81-09-28-2
7	477	281	113.2	1.19	0.25	1.189	1.190	6.885	FP-1-81-09-28-1
8	534	301	115.3	1.35	0.32	1.189	1.190	6.885	FP-1-81-09-25-3
9	590	311	112.4	1.49	0.37	1.189	1.189	6.886	FP-1-81-09-25-2
10	718	305	118.7	2.15	0.50	1.189	1.190	6.886	FP-1-81-09-25-1
11	805	276	122.6	2.23	0.59	1.189	1.190	6.885	FP-1-81-09-28-4
12	839	251	126.3	2.19	0.65	1.189	1.190	6.885	FP-1-81-09-29-1
13	874	215	133.6	2.34	0.73	1.189	1.191	6.886	FP-1-81-09-29-2
14	916	172	143.3	2.60	0.83	1.189	1.190	6.885	FP-1-81-09-29-3
15	958	150	143.4	2.93	0.91	1.189	1.190	6.885	FP-1-81-09-18-3
16	971	141	141.8	3.59	0.96	1.189	1.190	6.886	FP-1-81-09-18-2
17	1004	87	158.6	3.85	1.00	1.187	1.192	6.885	FP-1-81-09-18-1
18	1011	16	221.2	4.26	0.99	1.188	1.189	6.885	FP-1-81-09-17-5
19	1029	19	220.6	4.26	1.02	1.189	1.190	6.885	FP-1-81-09-17-3

C/P - Complete penetration N/A - Not available * - Not applicable
Note: Exit angles greater than 90° are ricochet angles.

TABLE A17a. (Continued)

	STRIKING SPEED (m/s)	EXIT SPEED (m/s)	EXIT ANGLE (deg)	LOS PENETRATION (cm)	PERPENDICULAR PENETRATION (cm)	RECOVERED PENETRATOR MIN. DIA (cm)	RECOVERED PENETRATOR MAX. DIA (cm)	RECOVERED PENETRATOR MASS (g)	SHOT IDENTIFICATION
20	1040	28	-9.6	C/P	C/P	1.189	1.190	6.886	FP-1-81-09-17-4
21	1052	N/A	N/A	C/P	C/P	1.189	1.190	6.886	FP-1-81-09-29-4
22	1062	52	-27.2	C/P	C/P	1.189	1.190	6.885	FP-1-81-09-17-2
23	1081	105	5.6	C/P	C/P	1.188	1.190	6.886	FP-1-81-09-16-5
24	1083	94	-3.3	C/P	C/P	1.189	1.190	6.885	FP-1-81-09-16-4
25	1087	102	9.7	C/P	C/P	1.189	1.190	6.886	FP-1-81-09-17-1
26	1095	N/A	N/A	C/P	C/P	1.189	1.191	6.886	FP-1-81-09-16-3
27	1141	226	32.2	C/P	C/P	1.189	1.190	6.886	FP-1-81-09-29-6
28	1177	297	37.9	C/P	C/P	1.189	1.190	6.885	FP-1-81-09-16-2
29	1199	N/A	N/A	C/P	C/P	1.189	1.191	6.886	FP-1-81-09-29-5
30	1246	441	47.2	C/P	C/P	1.188	1.192	6.885	FP-1-81-09-16-1
31	1339	565	51.8	C/P	C/P	1.191	1.195	6.885	FP-1-81-09-30-1
32	1399	N/A	N/A	C/P	C/P	1.185	1.193	6.885	FP-1-81-09-30-3
33	1405	661	54.3	C/P	C/P	1.185	1.194	6.885	FP-1-81-09-30-3

C/P - Complete penetration N/A - Not available * - Not applicable
Note: Exit angles greater than 90° are ricochet angles.

TABLE A17b. Target Effects Data For 15/32 Inch Spheres Impacting 1/2 Inch Aluminum At 60 Degrees

PENETRATOR CHARACTERISTICS		TARGET CHARACTERISTICS	
SHAPE	- Sphere (Ball Bearing)	SHAPE	- (7.6 or 10) x 30 cm. Plate
MATERIAL	- Steel	MATERIAL	- Aluminum 2024-T351
DIAMETER	- 1.191 cm.	THICKNESS	- 5.080 cm.
MASS	- 6.888 g.	HARDNESS	- 153 BHN
HARDNESS	- 65 Rc	IMPACT ANGLE	- 60°

	HOLE DIAMETERS				CRATER		GROOVE		REAR SURFACE BULGE	SHOT IDENTIFICATION
	ENTRANCE		EXIT		WIDTH	LENGTH	WIDTH	LENGTH		
	Min. (cm)	Max. (cm)	Min. (cm)	Max. (cm)	(cm)	(cm)	(cm)	(cm)	(cm)	
1	*	*	*	*	F 0.52	F 0.70	0.52	0.70	0.00	FP-1-81-10-29-4
2	*	*	*	*	F 0.56	F 0.77	0.56	0.77	0.00	FP-1-81-10-30-1
3	*	*	*	*	F 0.54	F 0.83	0.54	0.83	0.00	FP-1-81-09-28-3
4	*	*	*	*	F 0.69	F 0.97	0.69	0.97	0.00	FP-1-81-10-29-3
5	*	*	*	*	F 0.94	F 1.45	0.94	1.45	0.00	FP-1-81-10-29-2
6	*	1.00	*	0.91	F 1.24	F 1.91	0.97	1.91	0.02	FP-1-81-09-28-2
7	*	1.10	*	1.03	F 1.33	F 2.22	1.06	2.22	0.03	FP-1-81-09-28-1
8	*	1.07	*	1.02	F 1.33	F 2.47	1.17	2.47	0.06	FP-1-81-09-25-3
9	*	1.13	*	0.97	F 1.48	F 2.79	1.10	2.79	0.07	FP-1-81-09-25-2
10	*	1.09	*	1.39	F 1.61	F 3.38	1.28	3.38	0.11	FP-1-81-09-25-1
11	*	1.19	*	1.10	F 1.62	F 3.78	1.37	3.70	0.16	FP-1-81-09-28-4
12	*	1.18	*	1.01	F 1.77	F 3.98	1.35	3.75	0.17	FP-1-81-09-29-1
13	*	1.17	*	1.17	F 1.88	F 4.10	1.35	3.87	0.19	FP-1-81-09-29-2
14	*	1.08	*	1.17	F 1.93	F 4.26	1.37	4.11	0.28	FP-1-81-09-29-3
15	*	1.19	*	1.14	F 2.06	F 4.55	1.51	4.20	0.33	FP-1-81-09-18-3
16	*	1.09	*	1.15	F 2.09	F 4.60	1.44	4.25	0.36	FP-1-81-09-18-2
17	*	1.19	*	1.18	F 2.09	F 4.72	1.19	4.72	0.47	FP-1-81-09-18-1
18	*	1.19	*	1.10	F 2.10 R 1.39	F 4.53 R 2.11	1.46	4.23	0.85	FP-1-81-09-17-5

F - the entrance side of the target plate; R - the exit side of the target plate
N/A - Not available * - Not applicable

TABLE A17b. (Continued)

	HOLE DIAMETERS ENTRANCE Min. (cm)	HOLE DIAMETERS ENTRANCE Max. (cm)	HOLE DIAMETERS EXIT Min. (cm)	HOLE DIAMETERS EXIT Max. (cm)	CRATER WIDTH (cm)	CRATER LENGTH (cm)	GROOVE WIDTH (cm)	GROOVE LENGTH (cm)	REAR SURFACE BULGE (cm)	SHOT IDENTIFICATION
19	*	1.06	*	1.12	F 2.02	F 4.71	1.55	4.40	*	FP-1-81-09-17-3
					R 1.52	R 1.78				
20	*	1.09	*	1.18	F 2.06	F 4.47	1.39	4.24	*	FP-1-81-09-17-4
					R 2.59	R 3.04				
21	*	1.19	*	1.09	F 2.00	F 4.71	1.43	4.47	*	FP-1-81-09-29-4
					R 2.14	R 2.69				
22	*	1.15	*	1.07	F 2.11	F 4.59	1.46	4.43	*	FP-1-81-09-17-2
					R 2.42	R 2.76				
23	*	1.12	*	1.19	F 2.13	F 4.28	1.38	4.14	*	FP-1-81-09-16-5
					R 1.73	R 3.49				
24	*	1.11	*	1.15	F 2.14	F 4.33	1.46	4.29	*	FP-1-81-09-16-4
					R 2.08	R 3.09				
25	*	1.21	*	1.18	F 2.15	F 4.42	1.33	4.34	*	FP-1-81-09-17-1
					R 2.42	R 3.82				
26	*	1.15	*	1.18	F 2.12	F 4.60	1.48	4.49	*	FP-1-81-09-16-3
					R 2.15	R 3.52				
27	*	1.21	*	1.17	F 2.24	F 4.55	1.50	4.17	*	FP-1-81-09-29-6
					R 2.14	R 4.04				

F - the entrance side of the target plate; R - the exit side of the target plate
N/A - Not available * - Not applicable

TABLE A17b. (Continued)

	HOLE DIAMETERS ENTRANCE Min. (cm)	HOLE DIAMETERS ENTRANCE Max. (cm)	HOLE DIAMETERS EXIT Min. (cm)	HOLE DIAMETERS EXIT Max. (cm)	CRATER WIDTH (cm)	CRATER LENGTH (cm)	GROOVE WIDTH (cm)	GROOVE LENGTH (cm)	REAR SURFACE BULGE (cm)	SHOT IDENTIFICATION
28	*	1.18	*	1.19	F 2.25 R 2.39	F 4.55 R 4.12	1.34	4.01	*	FP-1-81-09-16-2
29	*	1.11	*	1.11	F 2.19 R 2.13	F 4.40 R 4.16	1.52	4.05	*	FP-1-81-09-29-5
30	*	1.10	*	1.11	F 2.19 R 2.19	F 4.28 R 4.14	1.57	3.80	*	FP-1-81-09-16-1
31	*	1.14	*	1.15	F 2.28 R 2.10	F 4.45 R 4.14	1.61	3.84	*	FP-1-81-09-30-1
32	*	1.07	*	1.07	F 2.17 R 2.11	F 4.34 R 4.49	1.40	3.73	*	FP-1-81-09-30-2
33	*	1.08	*	1.10	F 2.31 R 1.95	F 4.50 R 4.45	1.48	3.98	*	FP-1-81-09-30-3

F - the entrance side of the target plate; R - the exit side of the target plate
N/A - Not available * - Not applicable

TABLE A18a. Target Effects Data For 15/32 Inch Spheres Impacting 2 Inch Aluminum At 60 Degrees

PENETRATOR CHARACTERISTICS		TARGET CHARACTERISTICS	
SHAPE	- Sphere (Ball Bearing)	SHAPE	- (7.6 or 10) x 30 cm. Plate
MATERIAL	- Steel	MATERIAL	- Aluminum 24S-T
DIAMETER	- 1.191 cm.	THICKNESS	- 5.080 cm.
MASS	- 6.888 g.	HARDNESS	- 163 BHN
HARDNESS	- 65 Rc	IMPACT ANGLE	- 60°

	STRIKING SPEED (m/s)	EXIT SPEED (m/s)	EXIT ANGLE (deg)	LOS PENETRATION (cm)	PERPENDICULAR PENETRATION (cm)	RECOVERED PENETRATOR MIN. DIA (cm)	RECOVERED PENETRATOR MAX. DIA (cm)	RECOVERED PENETRATOR MASS (g)	SHOT IDENTIFICATION
1	308	208	109.9	0.72	0.17	1.191	1.192	6.887	FP-1-81-11-13-1
2	513	300	113.9	1.24	0.30	1.191	1.191	6.888	FP-1-81-11-13-2

C/P - Complete penetration N/A - Not available * - Not applicable
Note: Exit angles greater than 90° are ricochet angles.

TABLE A18b. Target Effects Data For 15/32 Inch Spheres Impacting 2 Inch Aluminum At 60 Degrees

PENETRATOR CHARACTERISTICS		TARGET CHARACTERISTICS	
SHAPE	- Sphere (Ball Bearing)	SHAPE	- (7.6 or 10) x 30 cm. Plate
MATERIAL	- Steel	MATERIAL	- Aluminum 24S-T
DIAMETER	- 1.191 cm.	THICKNESS	- 5.080 cm.
MASS	- 6.888 g.	HARDNESS	- 163 BHN
HARDNESS	- 65 Rc	IMPACT ANGLE	- 60°

	HOLE DIAMETERS				CRATER		GROOVE		REAR SURFACE BULGE	SHOT IDENTIFICATION
	ENTRANCE		EXIT		WIDTH	LENGTH	WIDTH	LENGTH		
	Min. (cm)	Max. (cm)	Min. (cm)	Max. (cm)	(cm)	(cm)	(cm)	(cm)	(cm)	
1	*	*	*	*	1.00	1.46	1.00	1.46	*	FP-1-81-11-13-1
2	*	*	*	*	1.54	2.32	1.10	2.32	*	FP-1-81-11-13-2

N/A - Not available * - Not applicable

TABLE A19 Mass Of Recovered Penetrator Fragments For Shots Where Breakup Occurred

Shot Identification	Individual Fragments (grams)							Total Recovered (grams)	Refer To Table
FP-1-82-01-15-1	0.792	*	*	*	*	*	*	0.792	A1
FP-1-79-01-18-3	N/A	*	*	*	*	*	*	*	A2
FP-1-78-08-08-4	N/A	*	*	*	*	*	*	*	A2
FP-1-79-01-18-1	N/A	*	*	*	*	*	*	*	A2
FP-1-79-01-18-2	N/A	*	*	*	*	*	*	*	A2
FP-1-78-08-08-2	N/A	*	*	*	*	*	*	*	A2
FP-1-79-01-17-1	N/A	*	*	*	*	*	*	*	A2
FP-1-78-08-08-3	N/A	*	*	*	*	*	*	*	A2
FP-1-79-01-17-2	N/A	*	*	*	*	*	*	*	A2
FP-1-79-01-18-4	N/A	*	*	*	*	*	*	*	A2
FP-1-81-03-23-2	N/A	*	*	*	*	*	*	*	A5
FP-1-81-09-15-7	0.668	0.372	*	*	*	*	*	1.040	A7
FP-1-81-10-05-4	0.935	*	*	*	*	*	*	0.935	A8
FP-1-81-10-05-3	0.534	*	*	*	*	*	*	0.534	A8
FP-1-81-11-10-2	0.161	0.026	*	*	*	*	*	0.187	A8
FP-1-81-10-06-3	0.286	0.194	*	*	*	*	*	0.480	A8
FP-1-81-10-08-2	0.147	0.038	*	*	*	*	*	0.185	A8
FP-1-81-11-10-1	N/A	*	*	*	*	*	*	*	A8
FP-1-81-11-09-1	0.081	0.054	0.043	0.033	0.021	0.017	*	0.249	A8
FP-1-81-10-08-1	0.169	*	*	*	*	*	*	0.169	A8
FP-1-81-11-09-2	0.058	0.056	0.028	0.025	*	*	*	0.167	A8
FP-1-81-10-06-4	0.295	*	*	*	*	*	*	0.295	A8
FP-1-81-11-06-1	0.160	0.031	**	*	*	*	*	0.191	A8
FP-1-81-11-06-2	0.140	*	*	*	*	*	*	0.140	A8
FP-1-81-08-21-3	1.923	1.922	1.012	0.637	*	*	*	5.494	A10
FP-1-81-06-12-1	3.397	3.484	*	*	*	*	*	6.881	A11
FP-1-81-06-17-3	0.975	0.915	0.485	0.441	0.244	0.238	*	3.298	A11
FP-1-81-06-17-2	N/A	*	*	*	*	*	*	*	A11
FP-1-81-06-17-1	1.530	0.216	*	*	*	*	*	1.746	A11
FP-1-81-09-02-1	5.103	1.101	0.460	*	*	*	*	6.664	A13
FP-1-81-09-04-1	1.792	1.512	1.460	0.323	0.269	0.239	0.132	5.727	A13
FP-1-81-08-25-3	1.827	1.705	1.027	0.769	0.187	0.123	0.121	5.755	A14
FP-1-81-08-25-2	1.638	1.450	0.757	0.554	*	*	*	4.399	A14
FP-1-81-08-25-1	1.433	0.813	0.547	0.392	0.322	0.219	0.143	3.869	A14
FP-1-81-07-24-3	2.252	0.675	0.612	*	*	*	*	3.539	A15

N/A - Not available * - Not applicable

APPENDIX B

INDIVIDUAL CURVE PLOTS OF EXIT SPEED, EXIT ANGLE, PERPENDICULAR DEPTH AND LOS DEPTH AS FUNCTIONS OF STRIKING SPEED

LIST OF FIGURES

LIST OF FIGURES (continued)

LIST OF FIGURES (continued)

LIST OF FIGURES (continued)

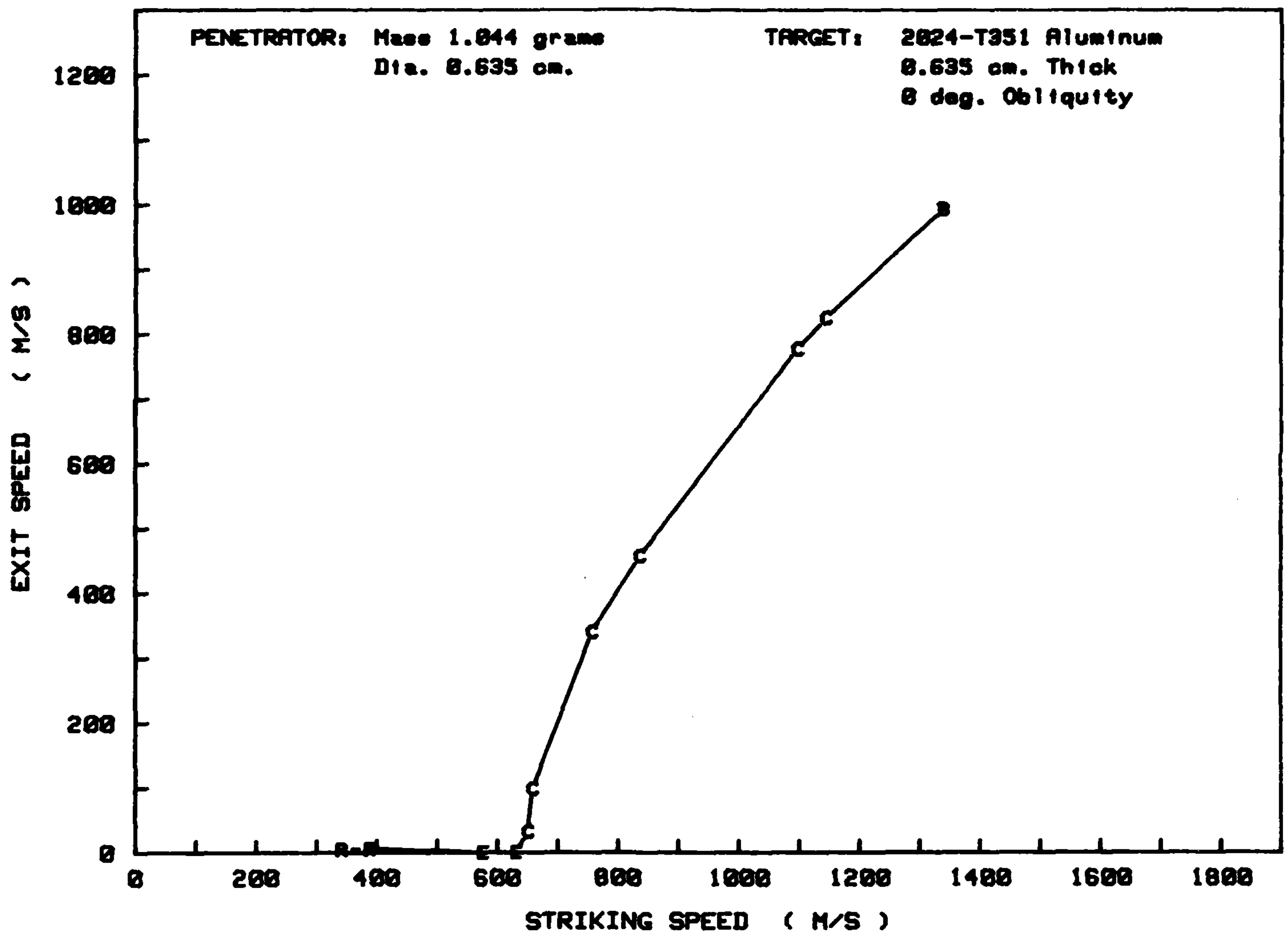


Figure 1a 1/4 in. Steel Sphere Impacting 1/4 Inch Thick Aluminum At 0 Degrees
(Exit Speed As A Function Of Striking Speed)

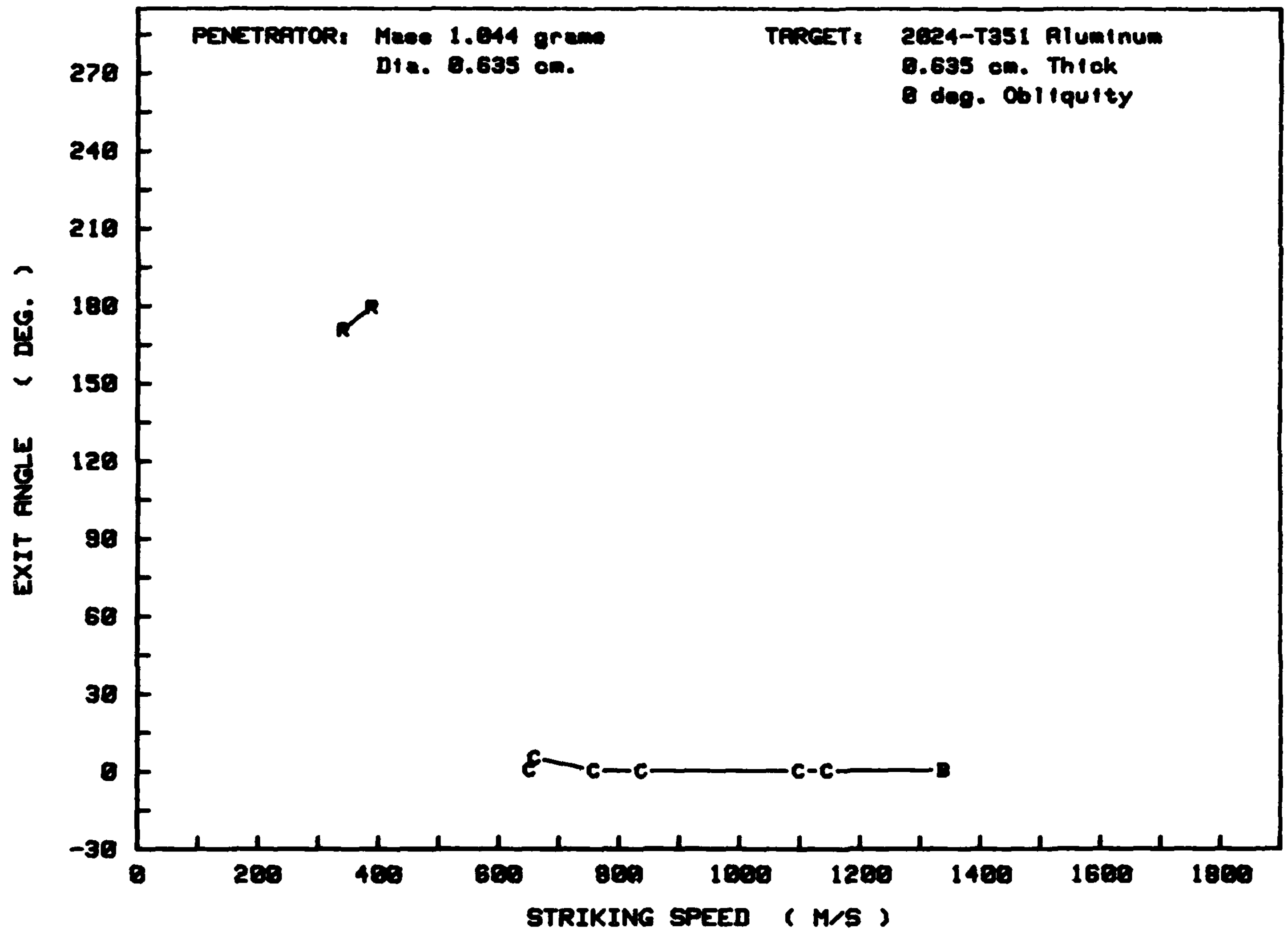


Figure 1b 1/4 in. Steel Sphere Impacting 1/4 Inch Thick Aluminum At 0 Degrees (Exit Angle As A Function Of Striking Speed)

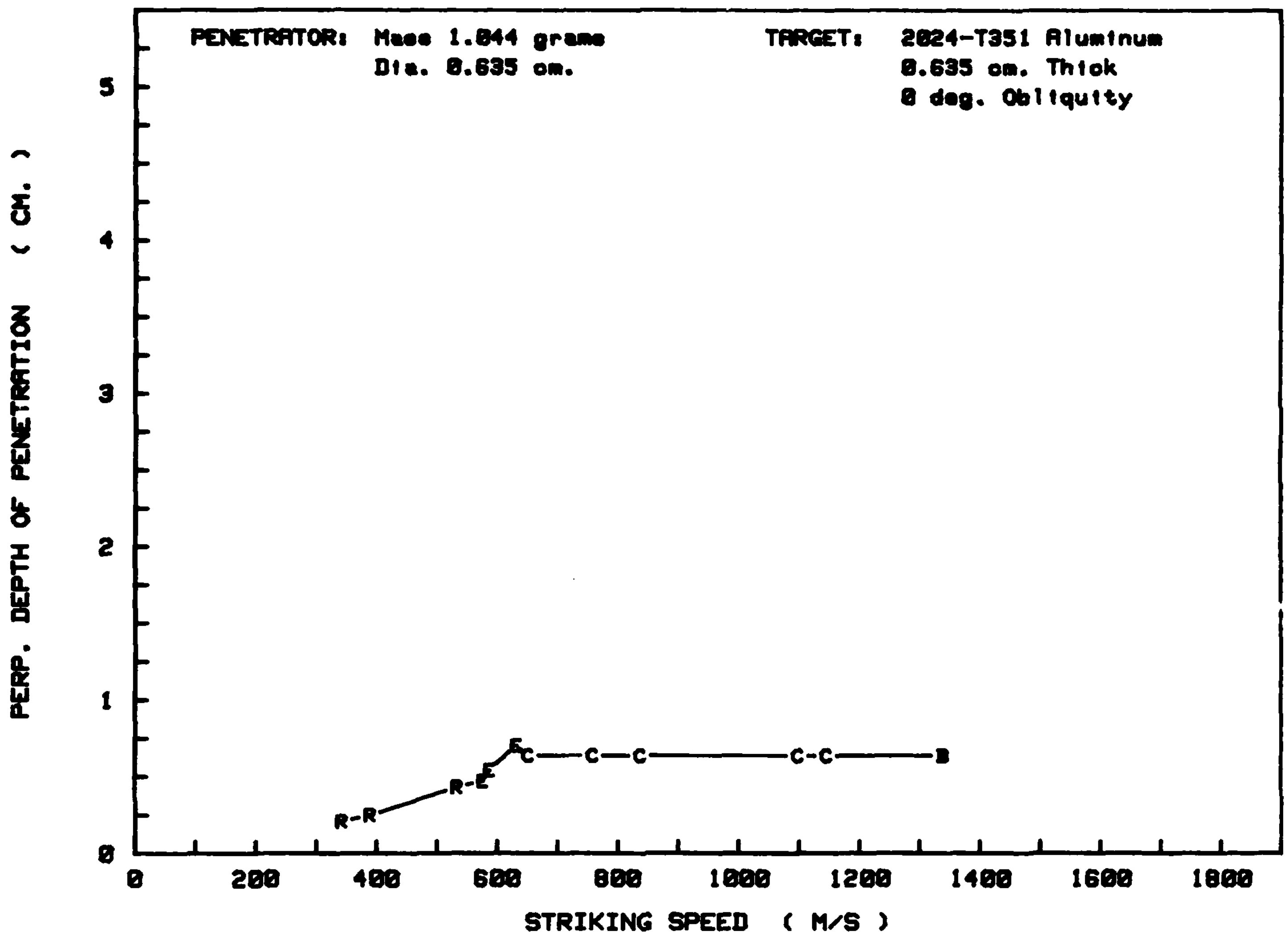


Figure 1c 1/4 in. Steel Sphere Impacting 1/4 Inch Thick Aluminum At 0 Degrees
(Perpendicular Depth As A Function Of Striking Speed)

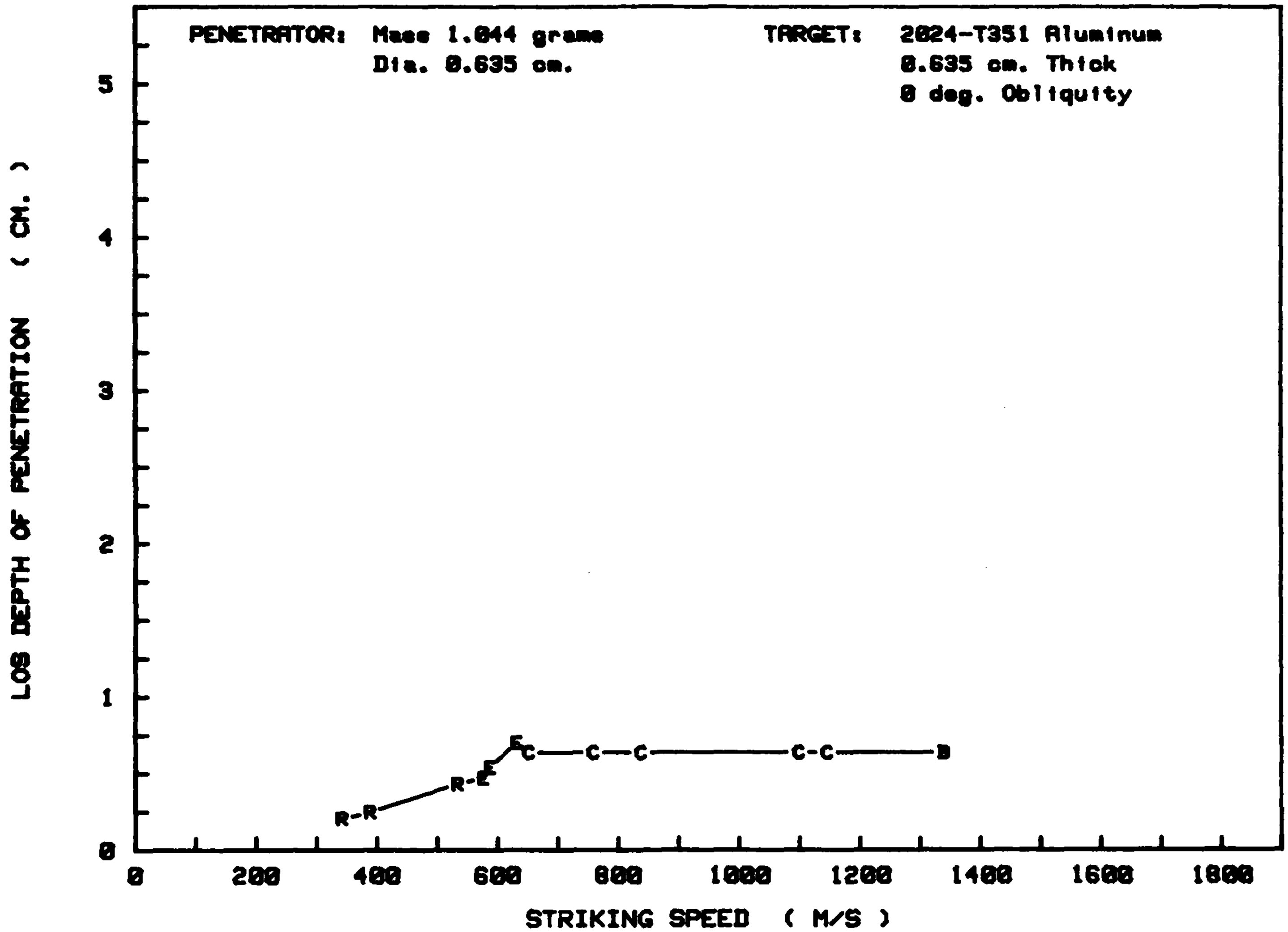


Figure 1d 1/4 in. Steel Sphere Impacting 1/4 Inch Thick Aluminum At 0 Degrees
(Line-of-Sight Depth As A Function Of Striking Speed)

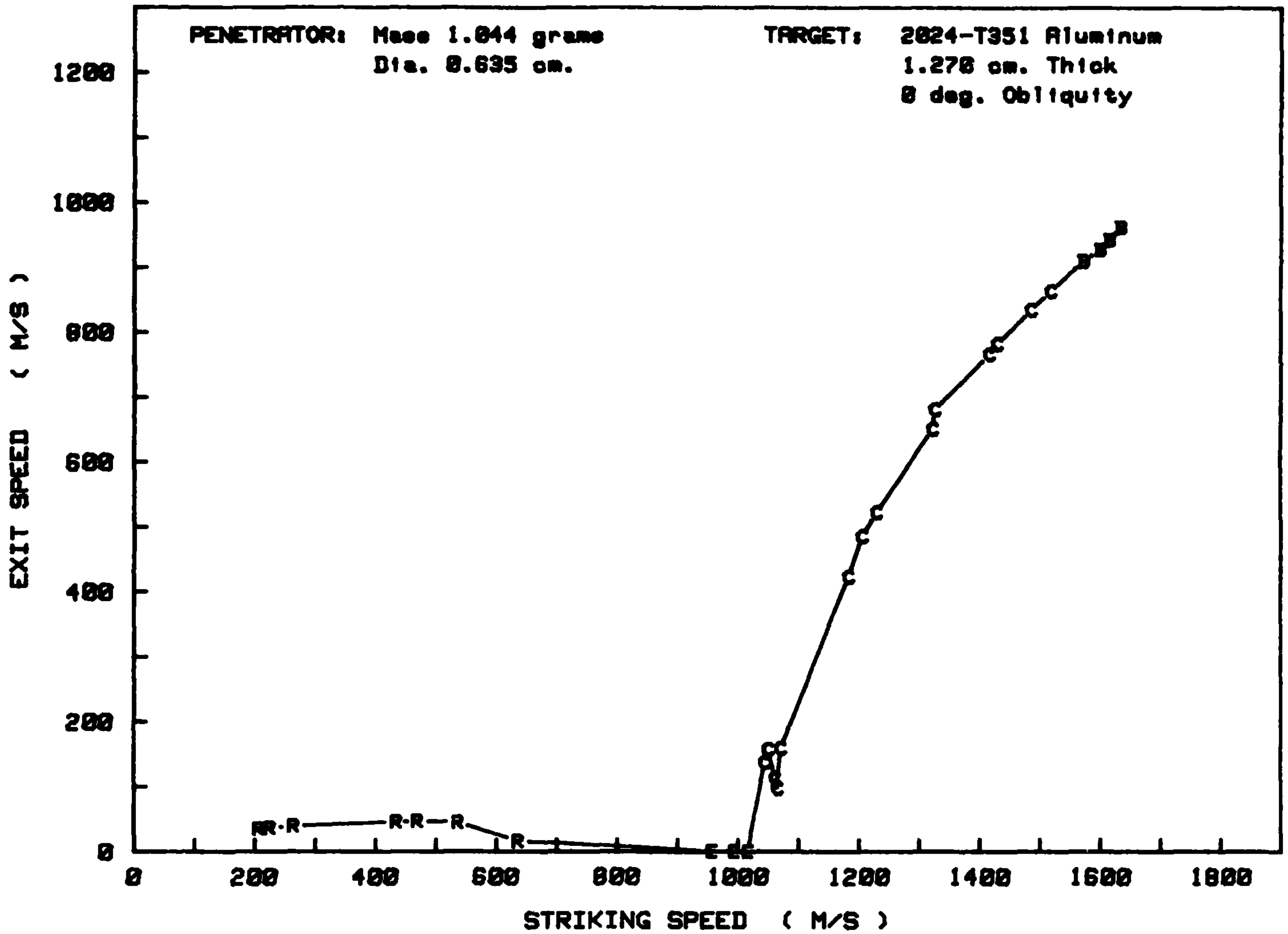


Figure 2a 1/4 in. Steel Sphere Impacting 1/2 Inch Thick Aluminum At 0 Degrees
(Exit Speed As A Function Of Striking Speed)

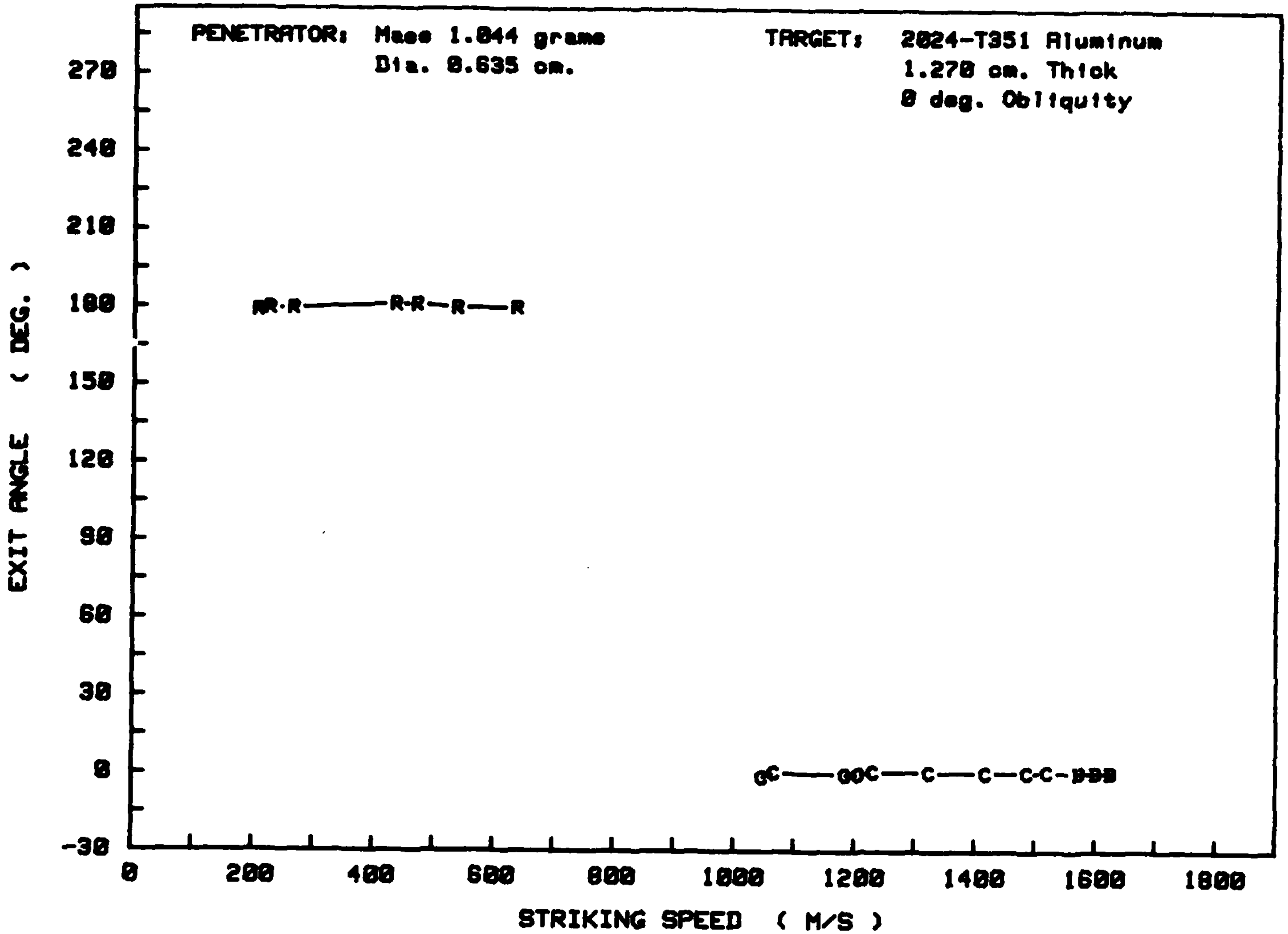


Figure 2b 1/4 in. Steel Sphere Impacting 1/2 Inch Thick Aluminum At 0 Degrees
(Exit Angle As A Function Of Striking Speed)

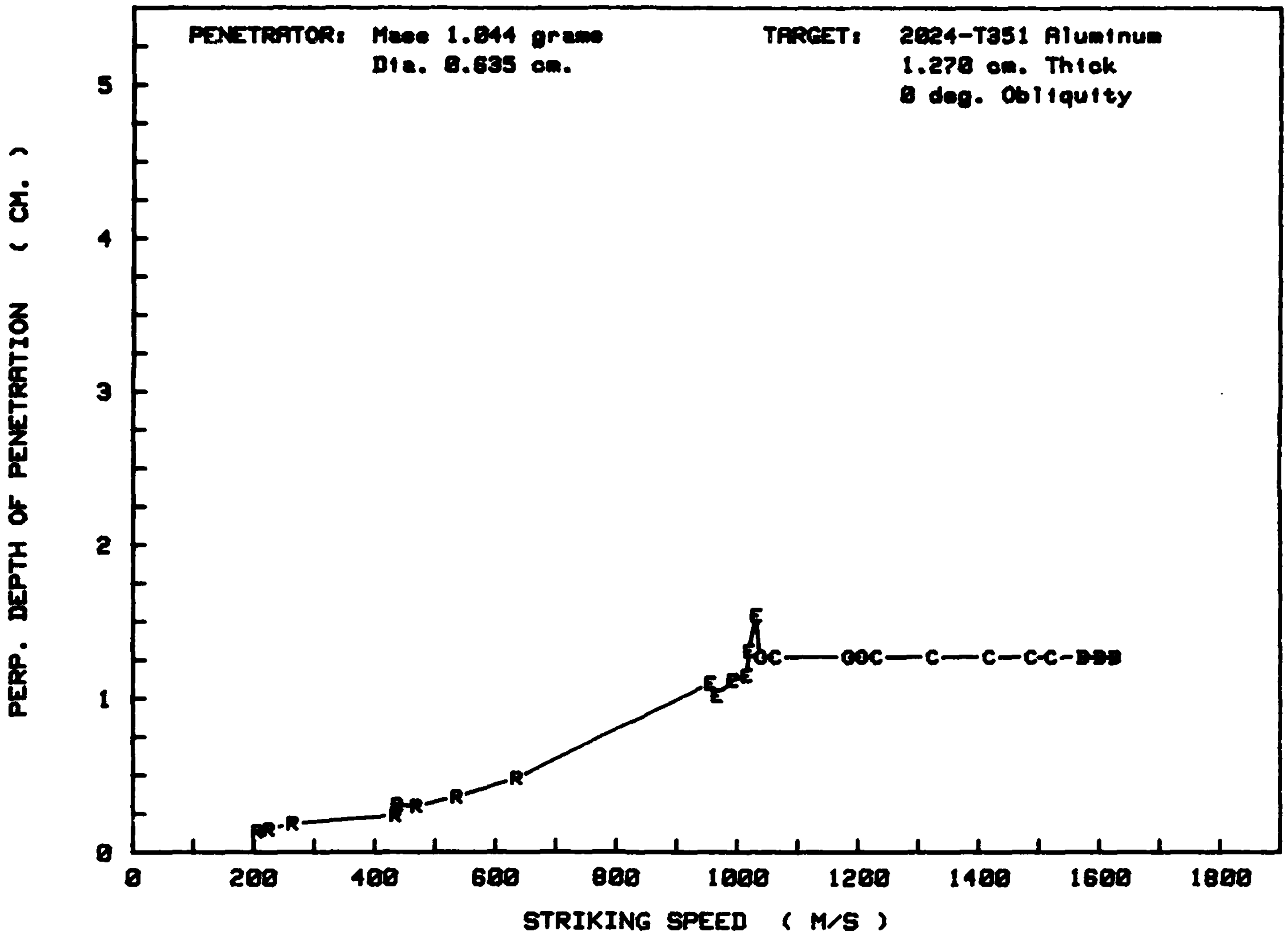


Figure 2c 1/4 in. Steel Sphere Impacting 1/2 Inch Thick Aluminum At 0 Degrees
(Perpendicular Depth As A Function Of Striking Speed)

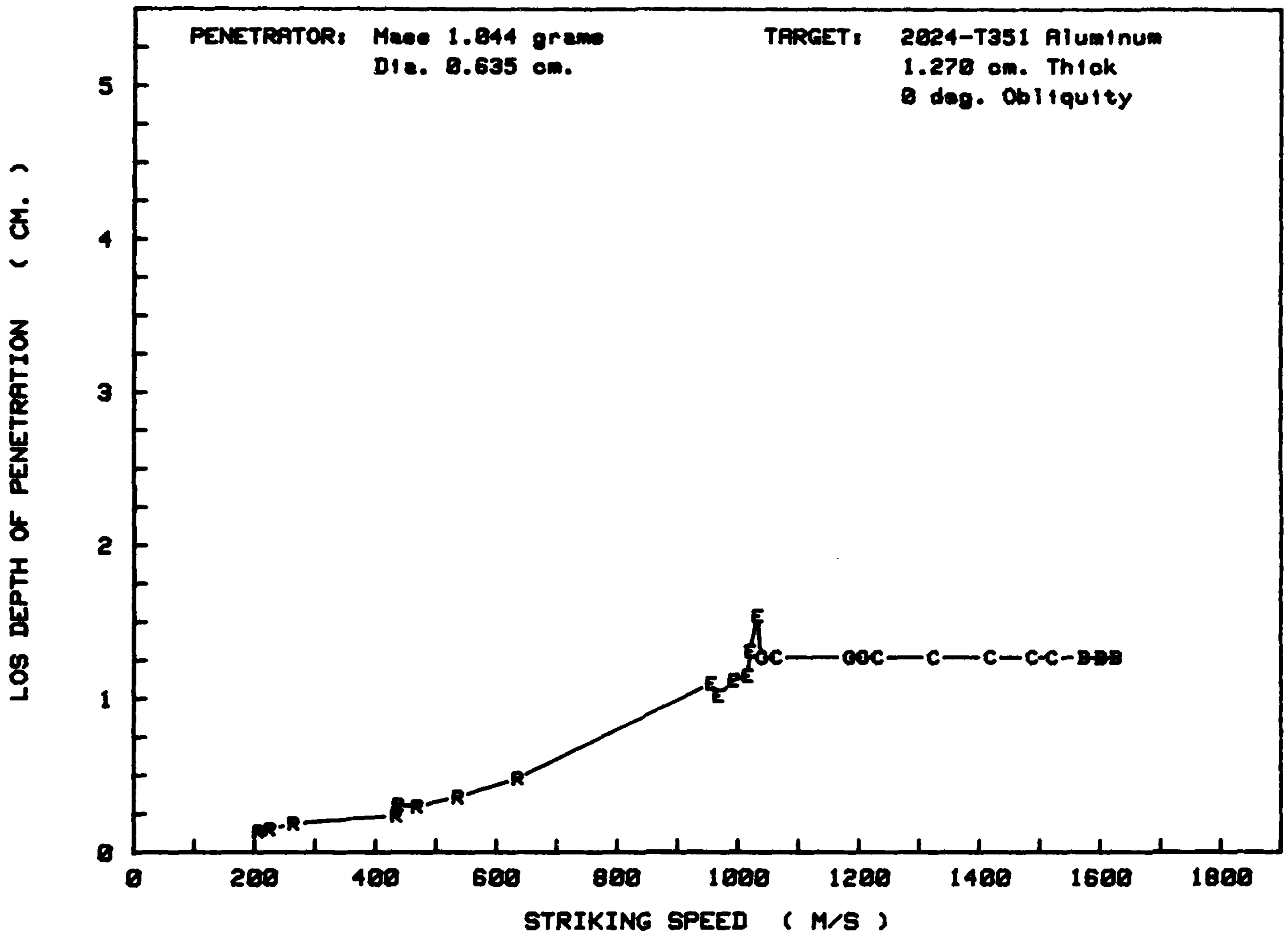


Figure 2d 1/4 in. Steel Sphere Impacting 1/2 Inch Thick Aluminum At 0 Degrees
(Line-of-Sight Depth As A Function Of Striking Speed)

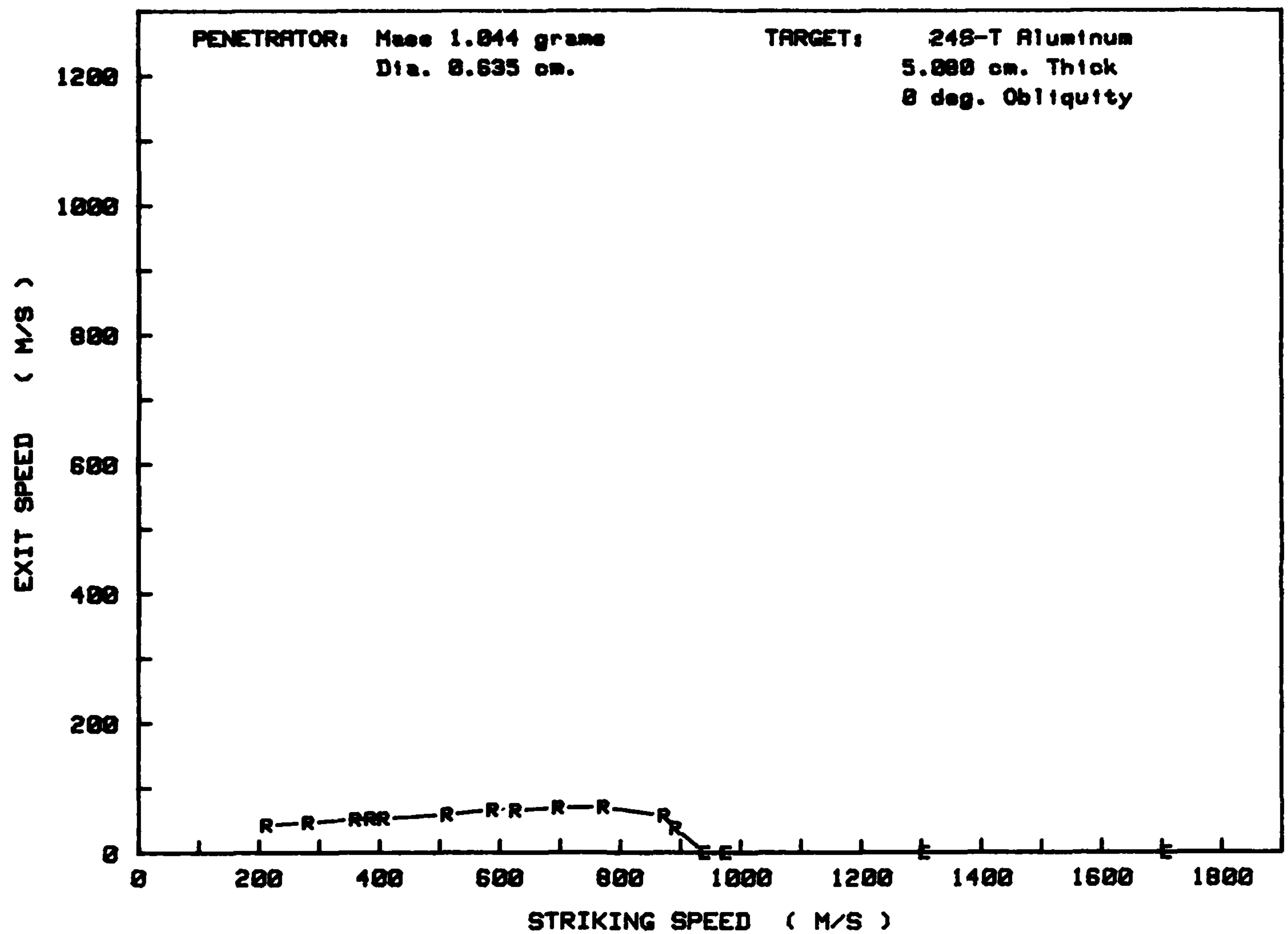


Figure 3a 1/4 in. Steel Sphere Impacting 2 Inch Thick Aluminum At 0 Degrees
(Exit Speed As A Function Of Striking Speed)

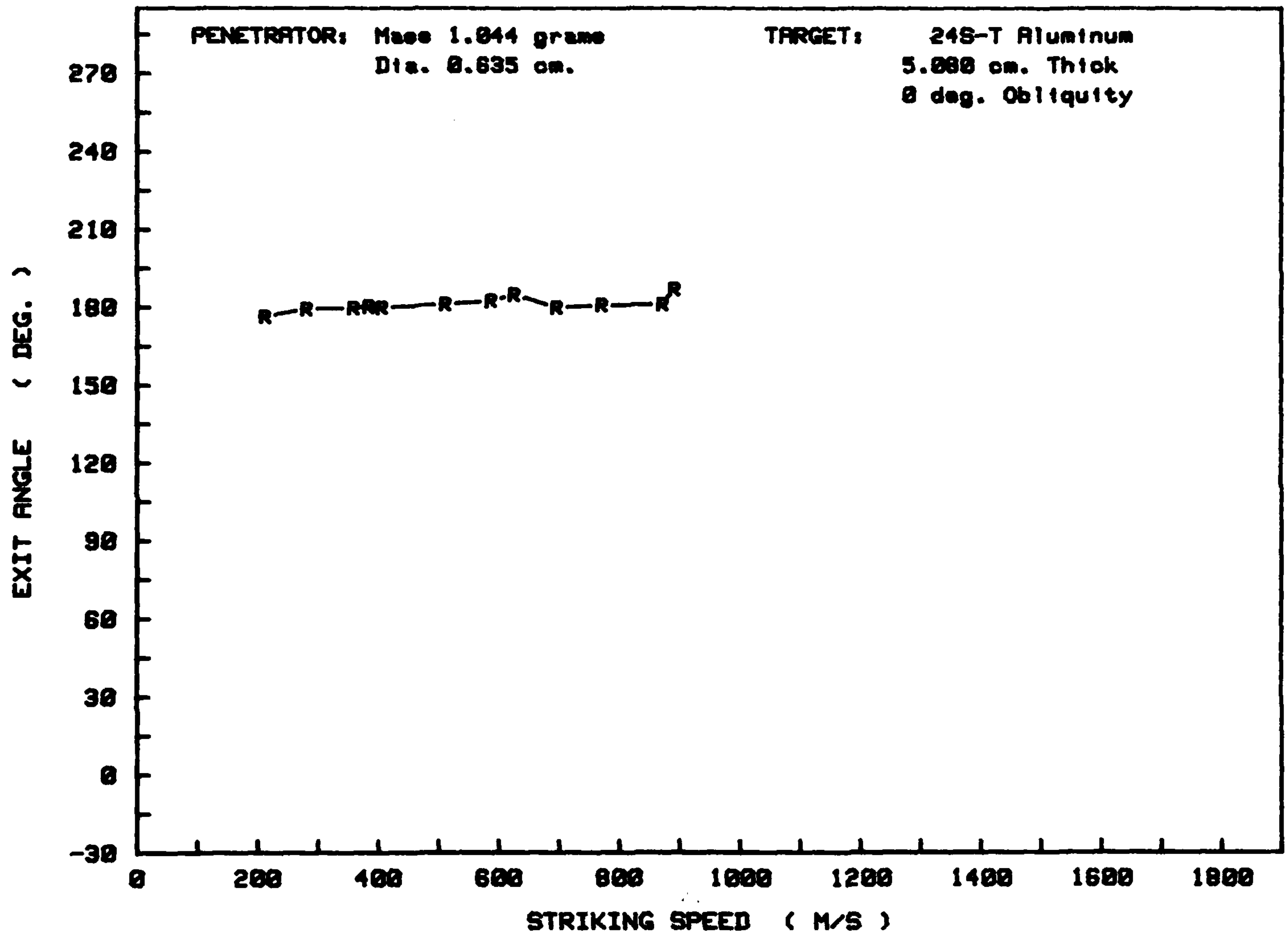


Figure 3b 1/4 in. Steel Sphere Impacting 2 Inch Thick Aluminum At 0 Degrees
(Exit Angle As A Function Of Striking Speed)

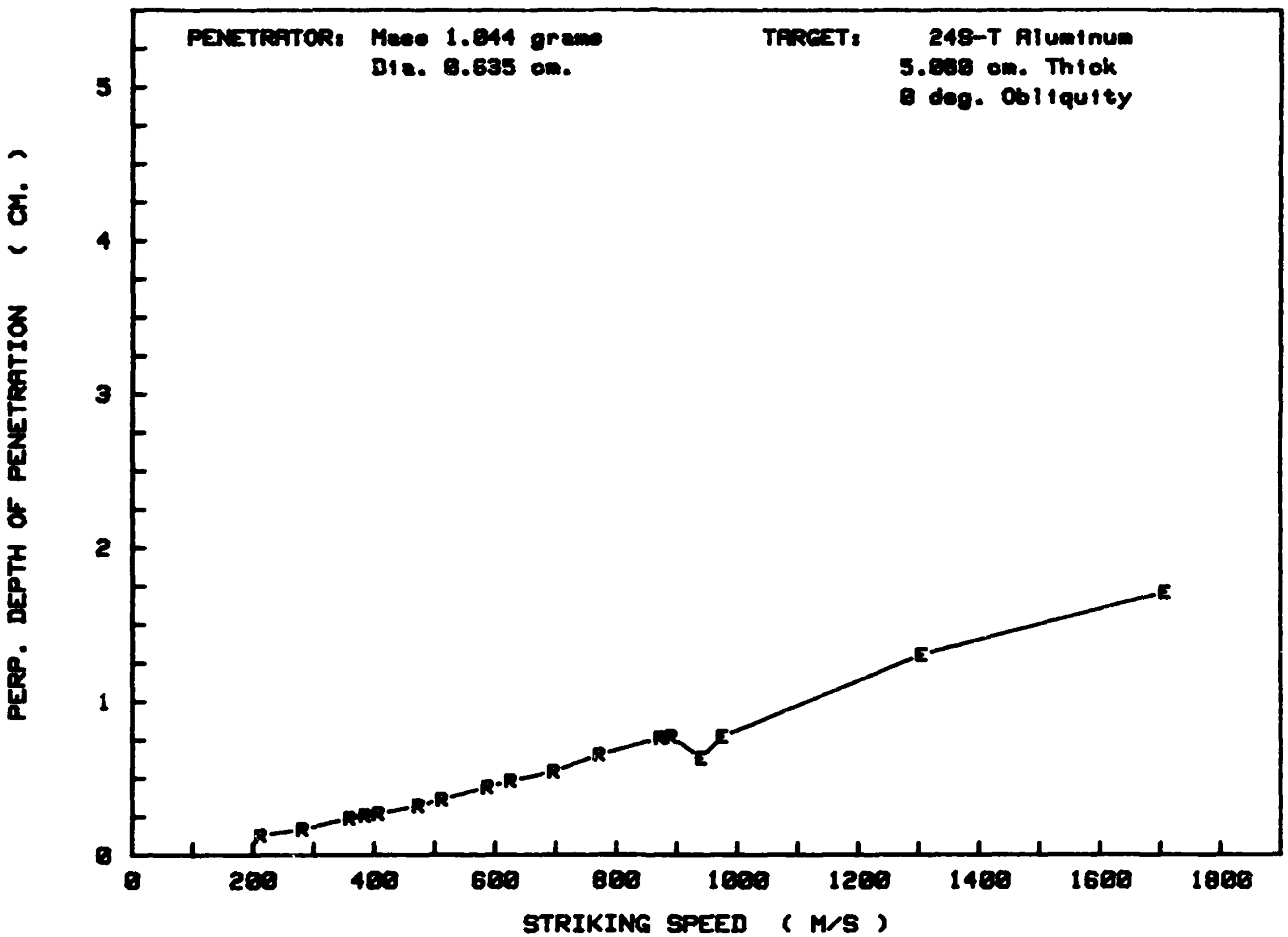


Figure 3c 1/4 in. Steel Sphere Impacting 2 Inch Thick Aluminum At 0 Degrees
(Perpendicular Depth As A Function Of Striking Speed)

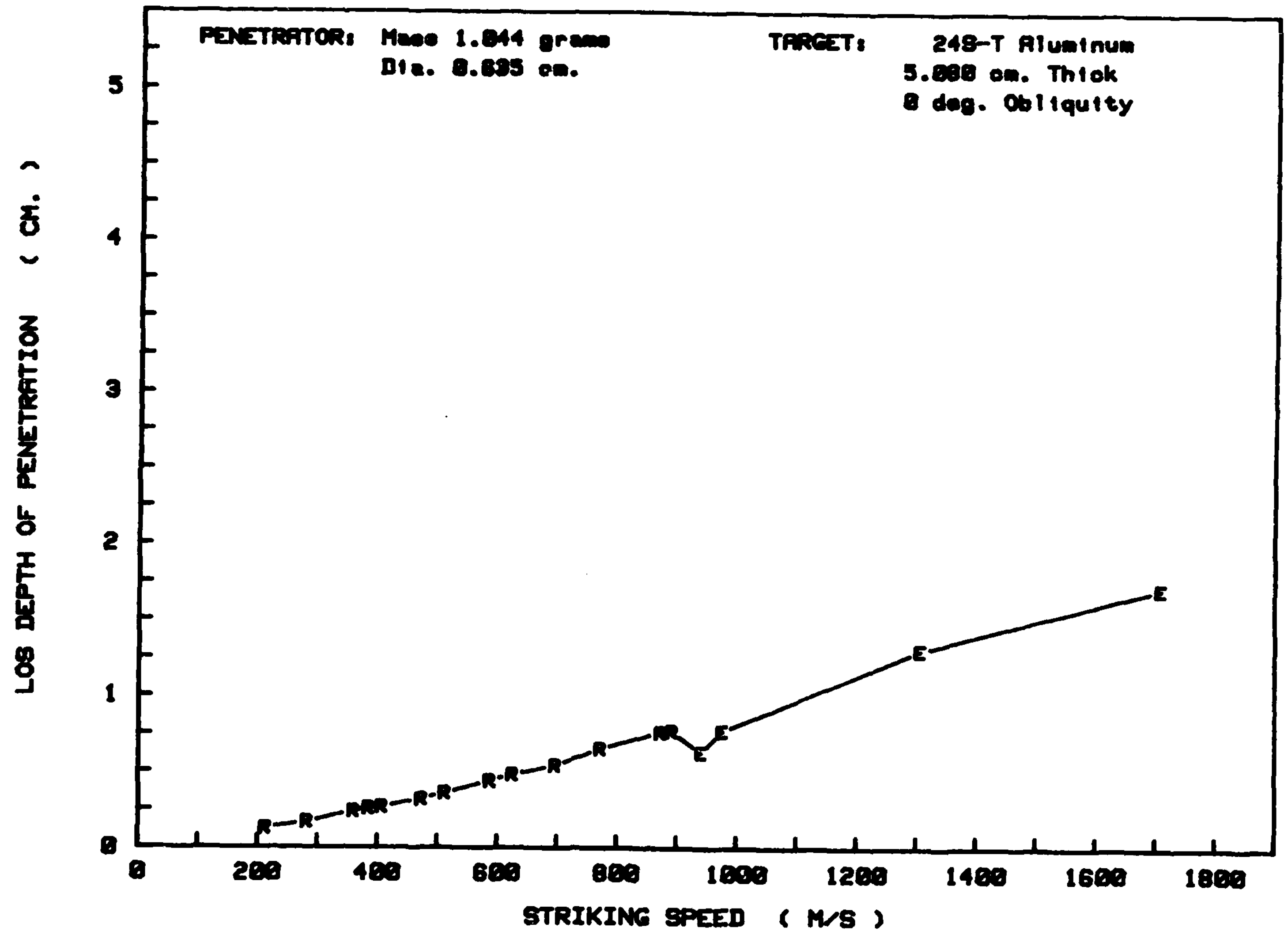


Figure 3d 1/4 in. Steel Sphere Impacting 2 Inch Thick Aluminum At 0 Degrees
(Line-of-Sight Depth As A Function Of Striking Speed)

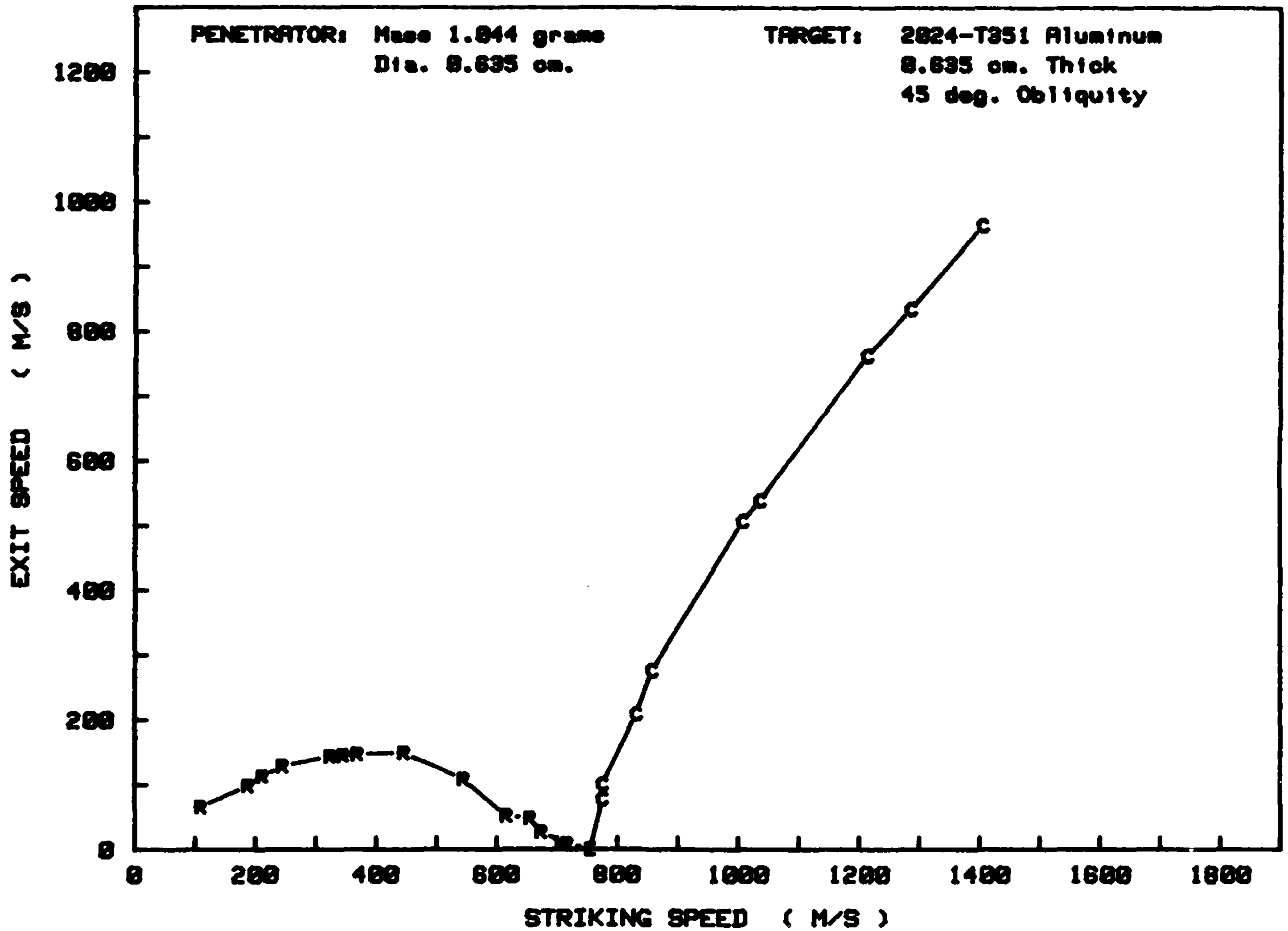


Figure 4a 1/4 in. Steel Sphere Impacting 1/4 Inch Thick Aluminum At 45 Degrees
(Exit Speed As A Function Of Striking Speed)

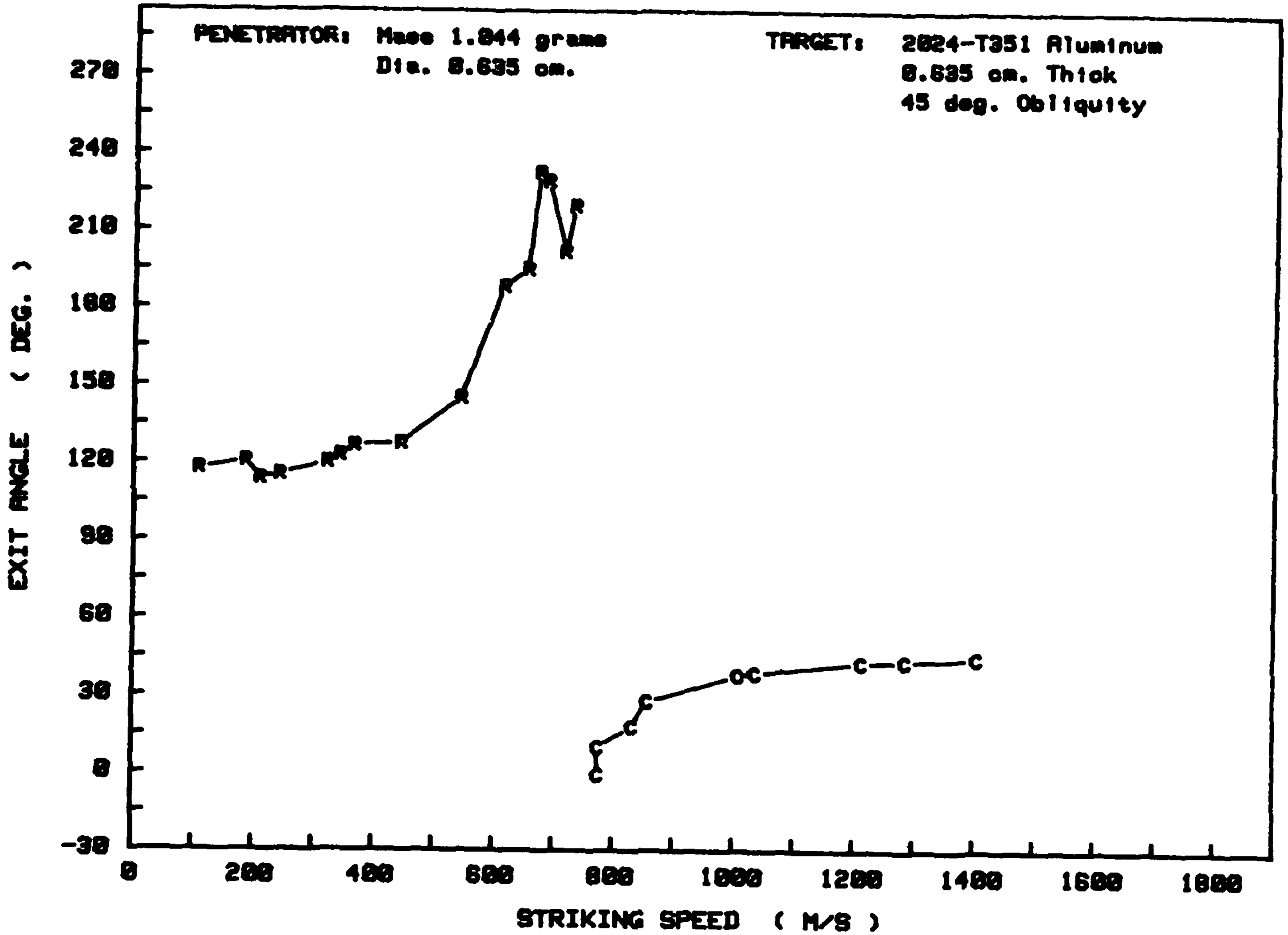


Figure 4b 1/4 in. Steel Sphere Impacting 1/4 Inch Thick Aluminum At 45 Degrees (Exit Angle As A Function Of Striking Speed)

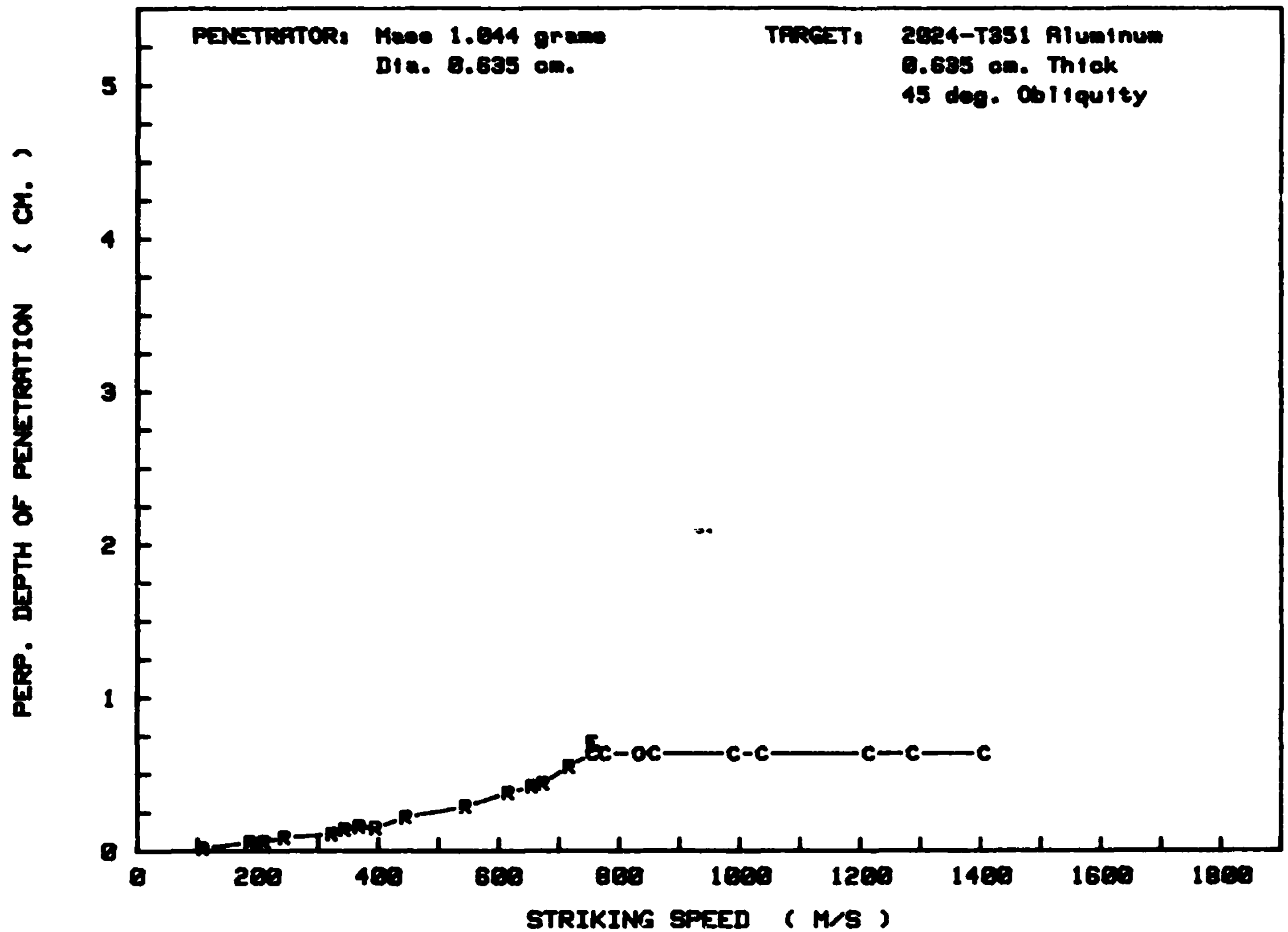


Figure 4c 1/4 in. Steel Sphere Impacting 1/4 Inch Thick Aluminum At 45 Degrees
(Perpendicular Depth As A Function Of Striking Speed)

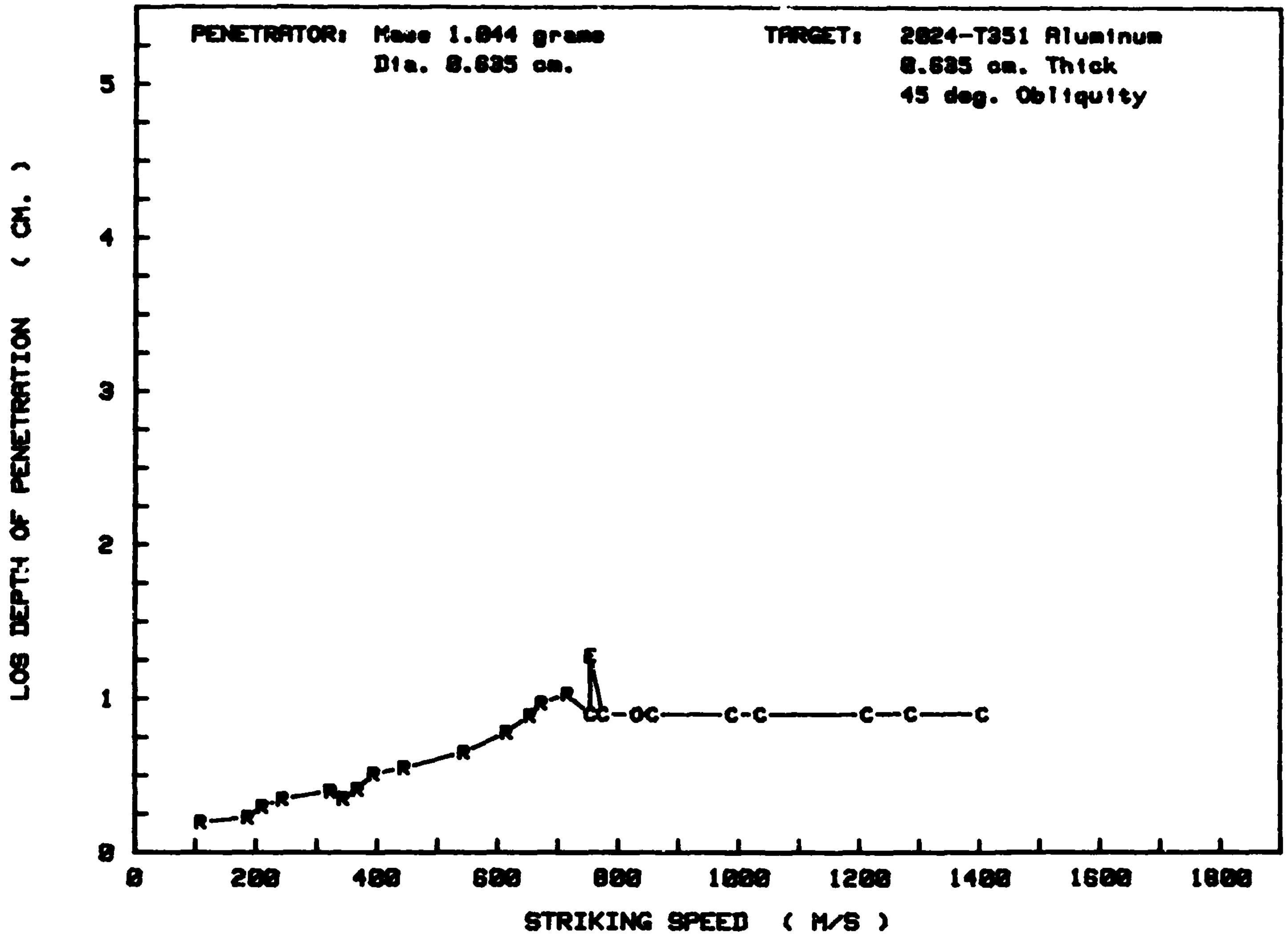


Figure 4d 1/4 in. Steel Sphere Impacting 1/4 Inch Thick Aluminum At 45 Degrees
(Line-of-Sight Depth As A Function Of Striking Speed)

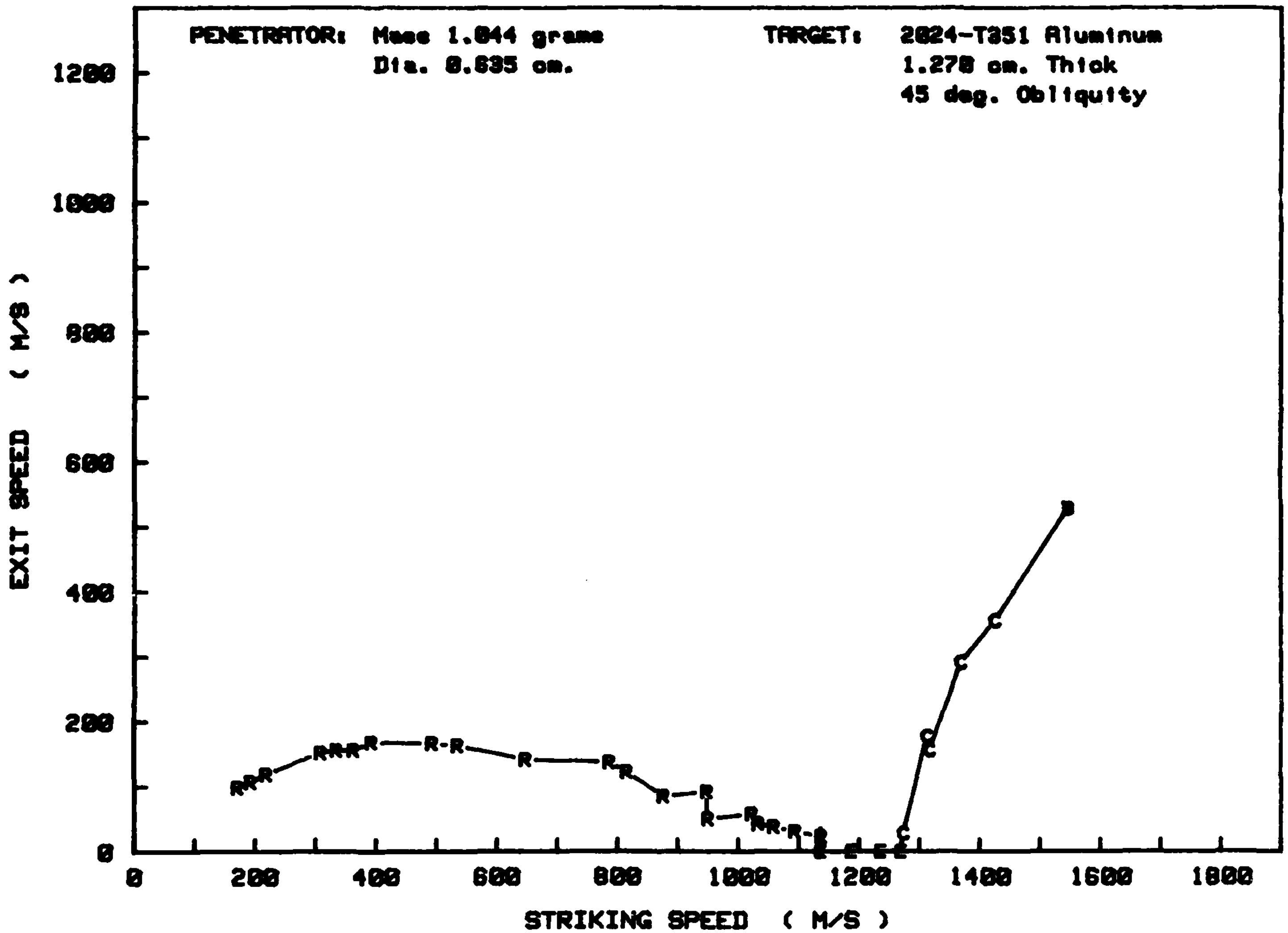


Figure 5a 1/4 in. Steel Sphere Impacting 1/2 Inch Thick Aluminum At 45 Degrees (Exit Speed As A Function Of Striking Speed)

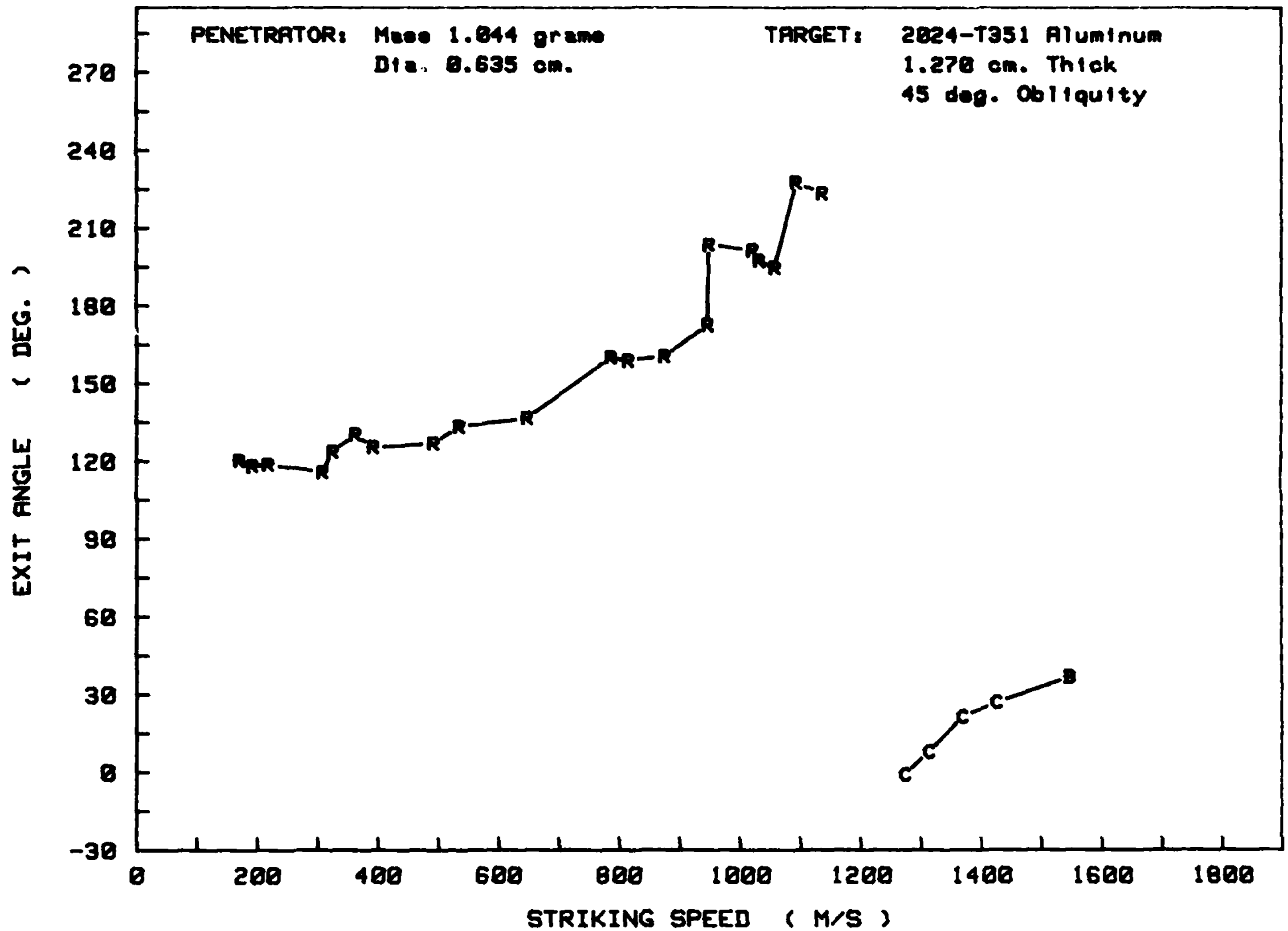


Figure 5b 1/4 in. Steel Sphere Impacting 1/2 Inch Thick Aluminum At 45 Degrees
(Exit Angle As A Function Of Striking Speed)

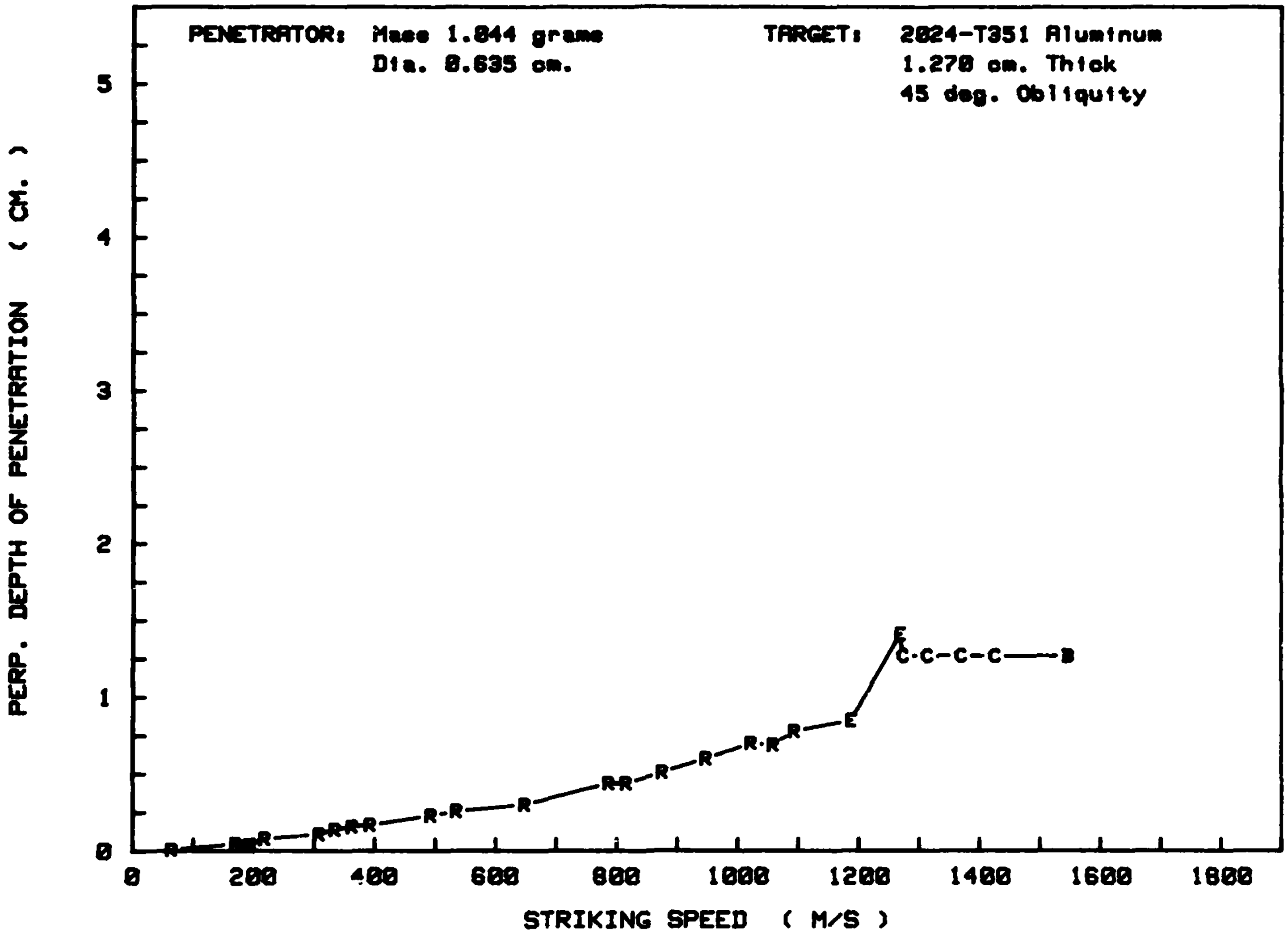


Figure 5c 1/4 in. Steel Sphere Impacting 1/2 Inch Thick Aluminum At 45 Degrees
(Perpendicular Depth As A Function Of Striking Speed)

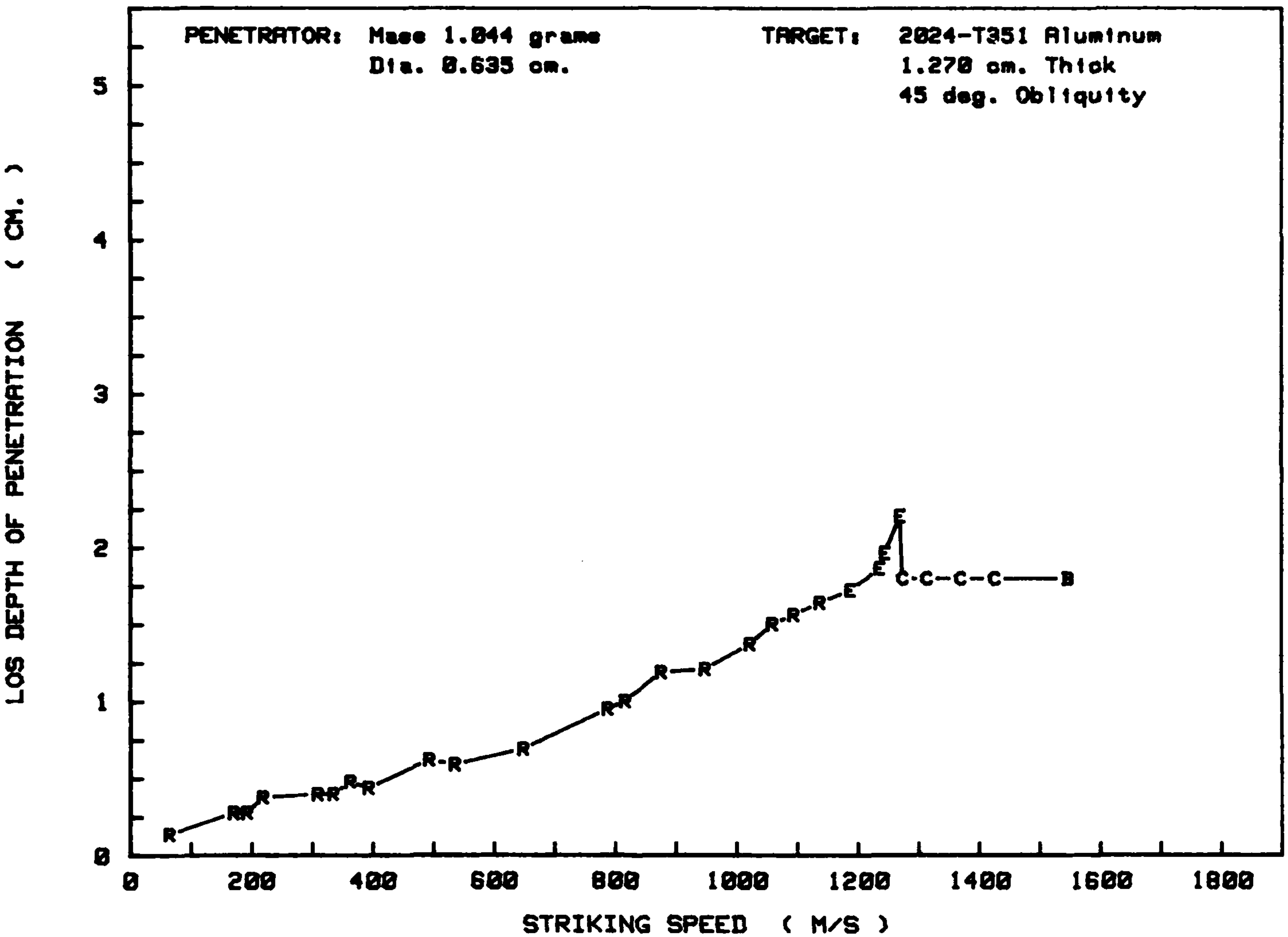


Figure 5d 1/4 in. Steel Sphere Impacting 1/2 Inch Thick Aluminum At 45 Degrees
(Line-of-Sight Depth As A Function Of Striking Speed)

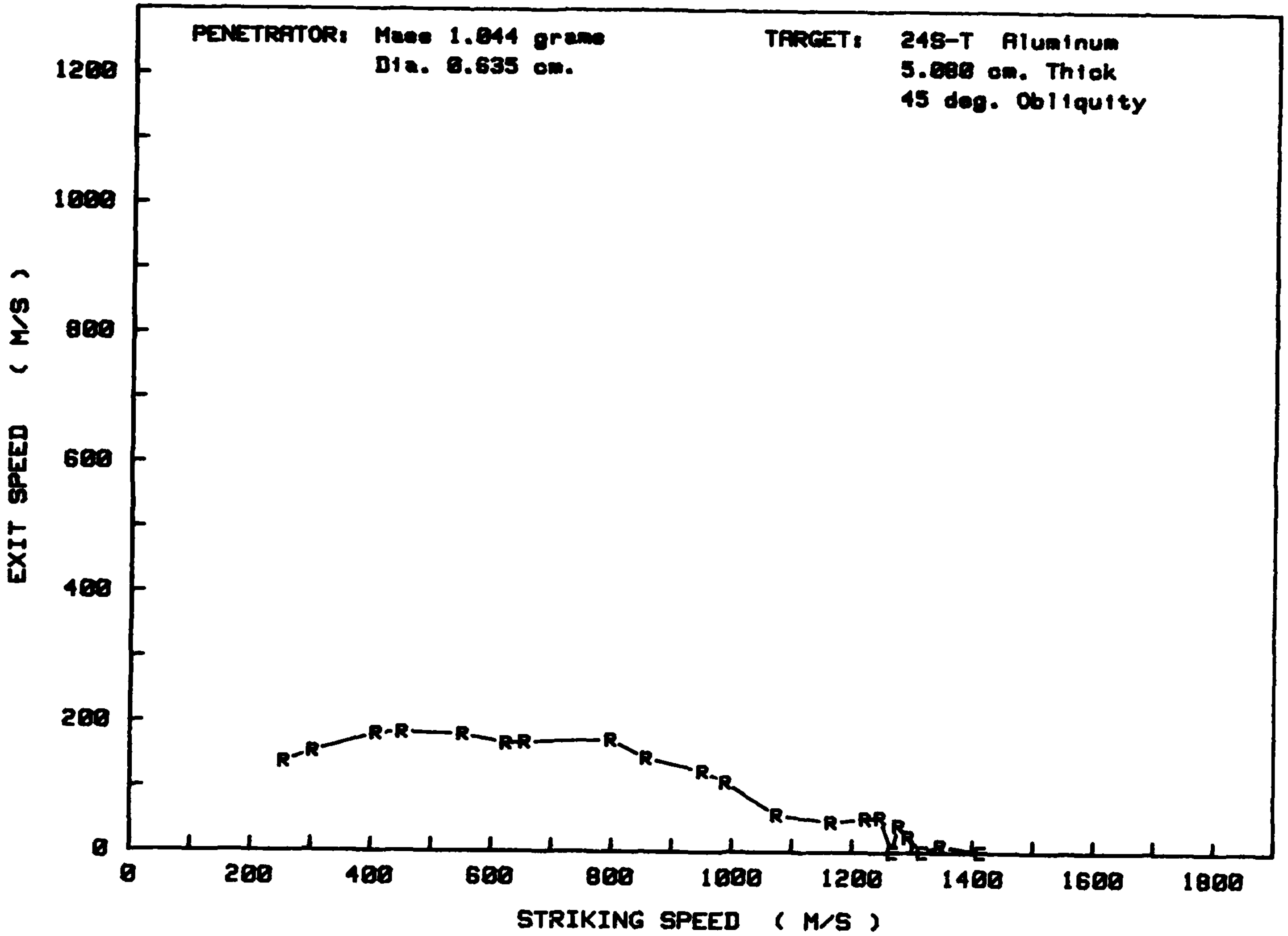


Figure 6a 1/4 in. Steel Sphere Impacting 2 Inch Thick Aluminum At 45 Degrees (Exit Speed As A Function Of Striking Speed)

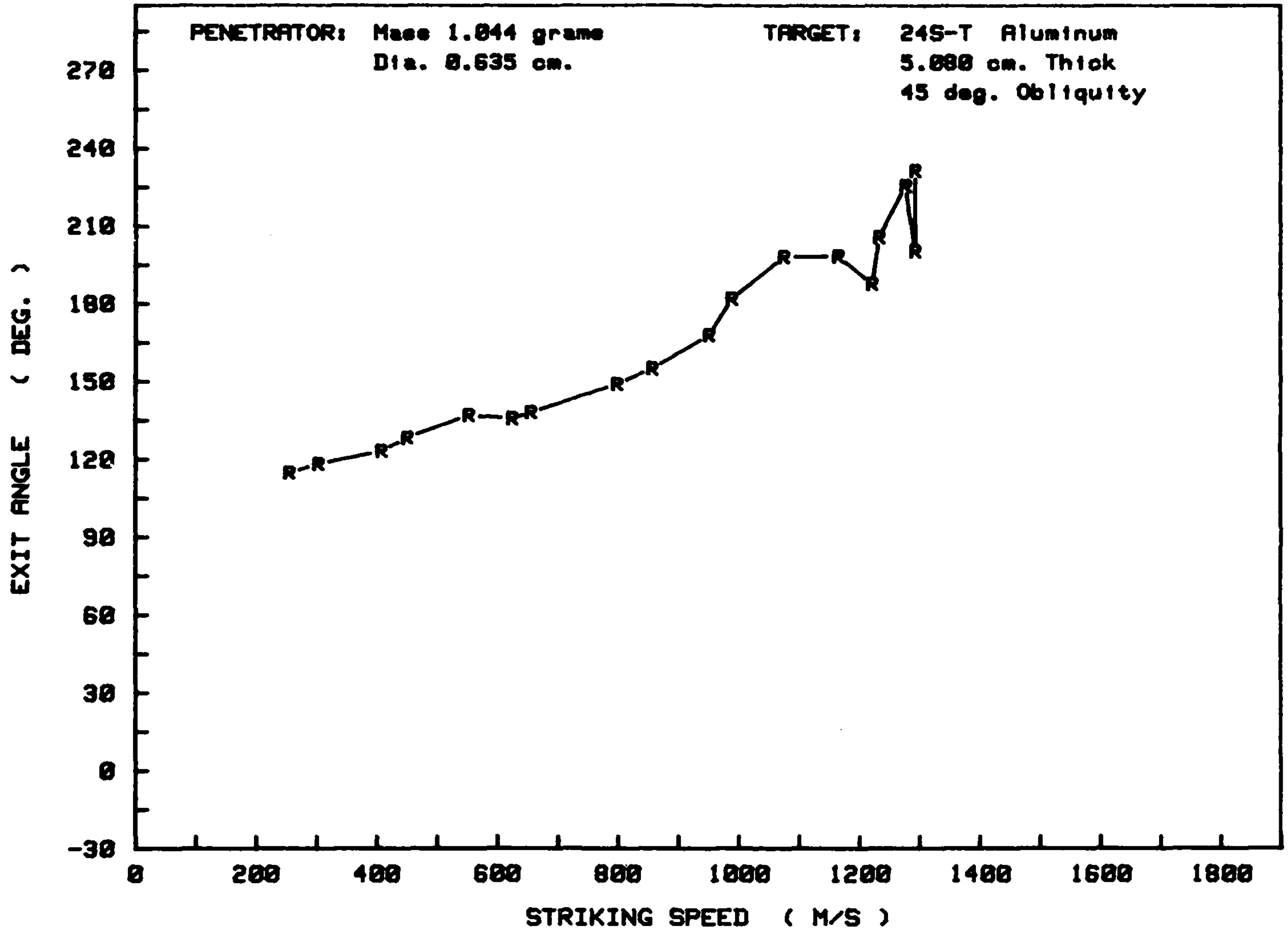


Figure 6b 1/4 in. Steel Sphere Impacting 2 Inch Thick Aluminum At 45 Degrees
(Exit Angle As A Function Of Striking Speed)

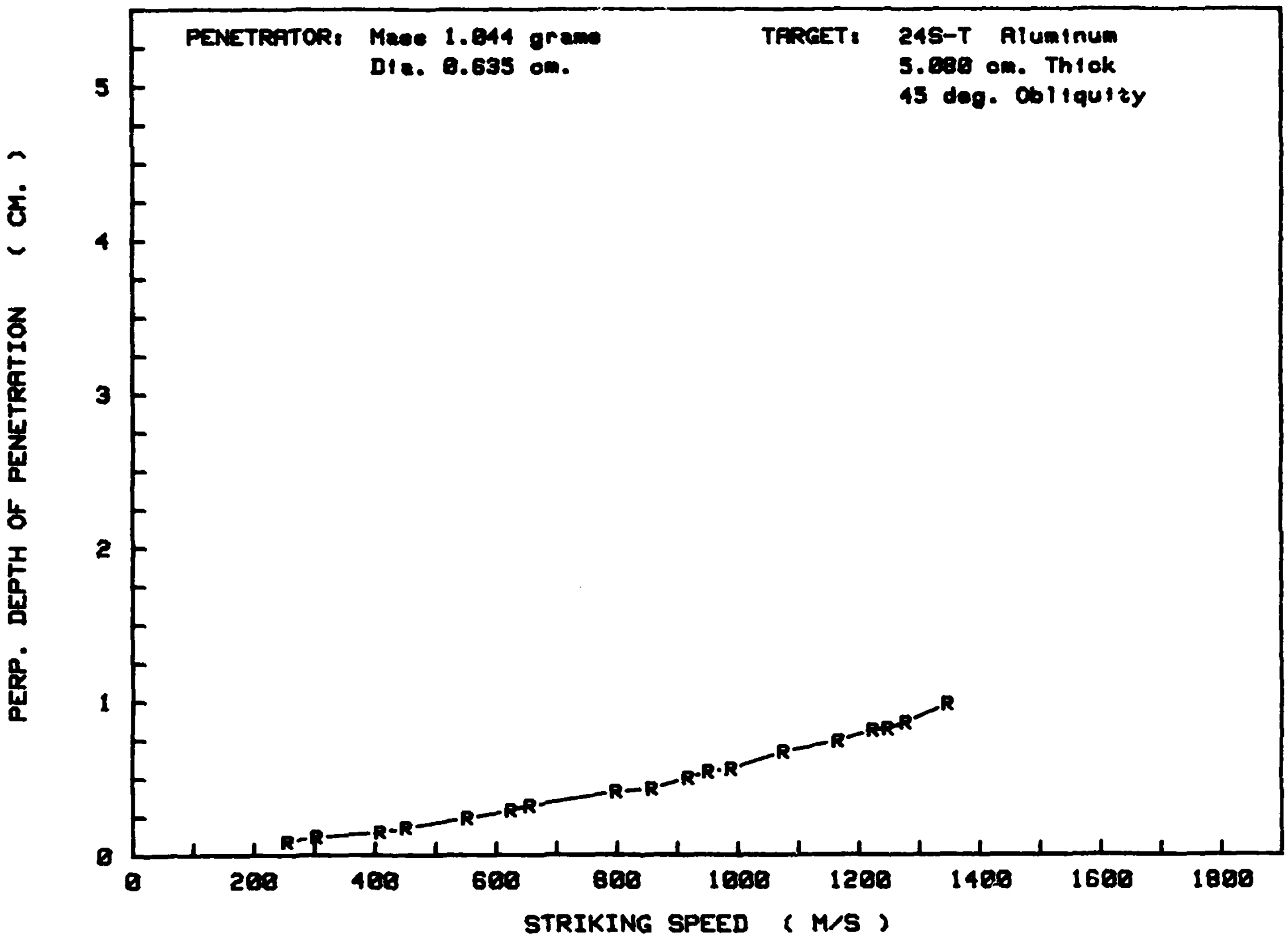


Figure 6c 1/4 in. Steel Sphere Impacting 2 Inch Thick Aluminum At 45 Degrees
(Perpendicular Depth As A Function Of Striking Speed)

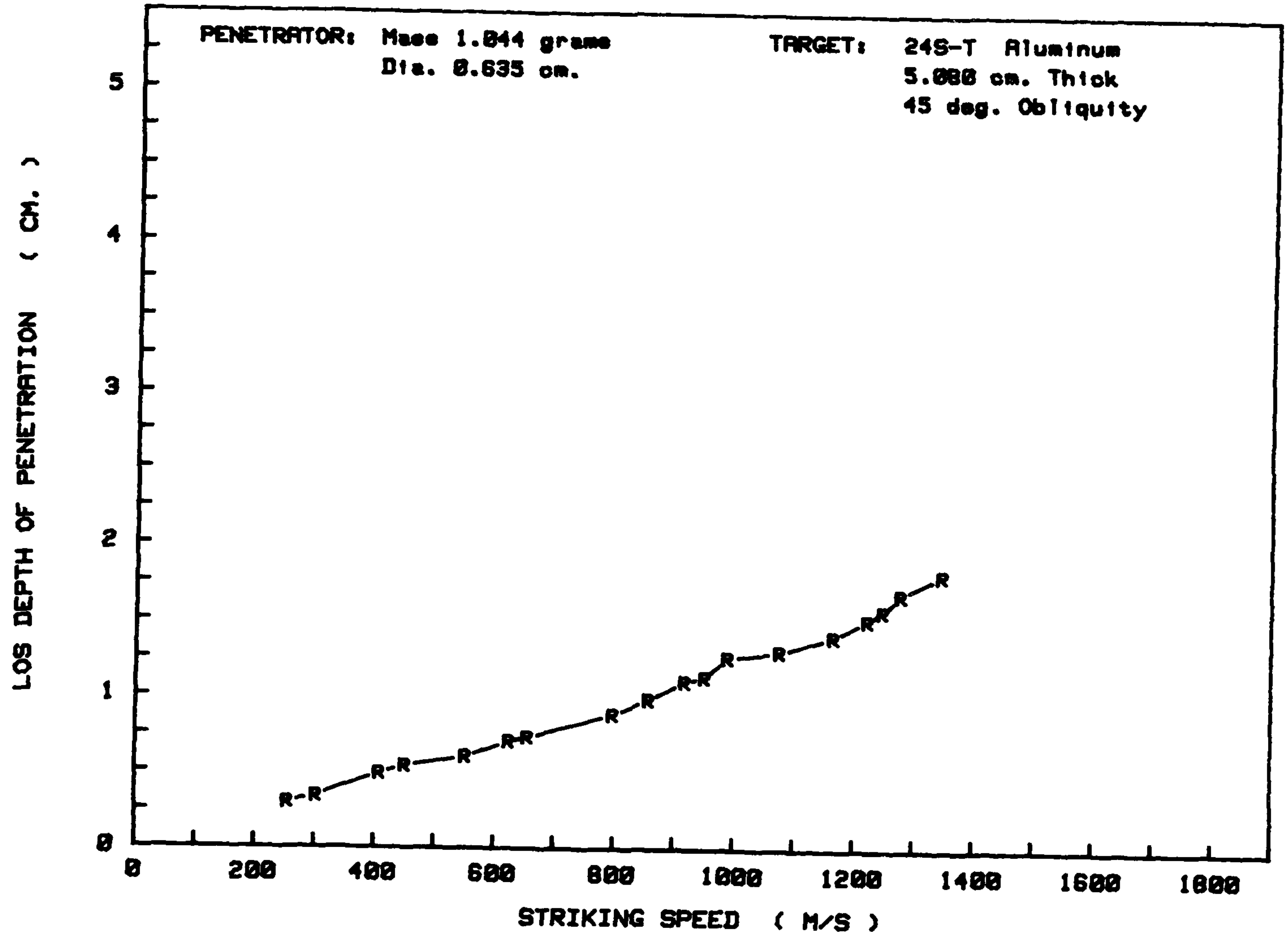


Figure 6d 1/4 in. Steel Sphere Impacting 2 Inch Thick Aluminum At 45 Degrees
(Line-of-Sight Depth As A Function Of Striking Speed)

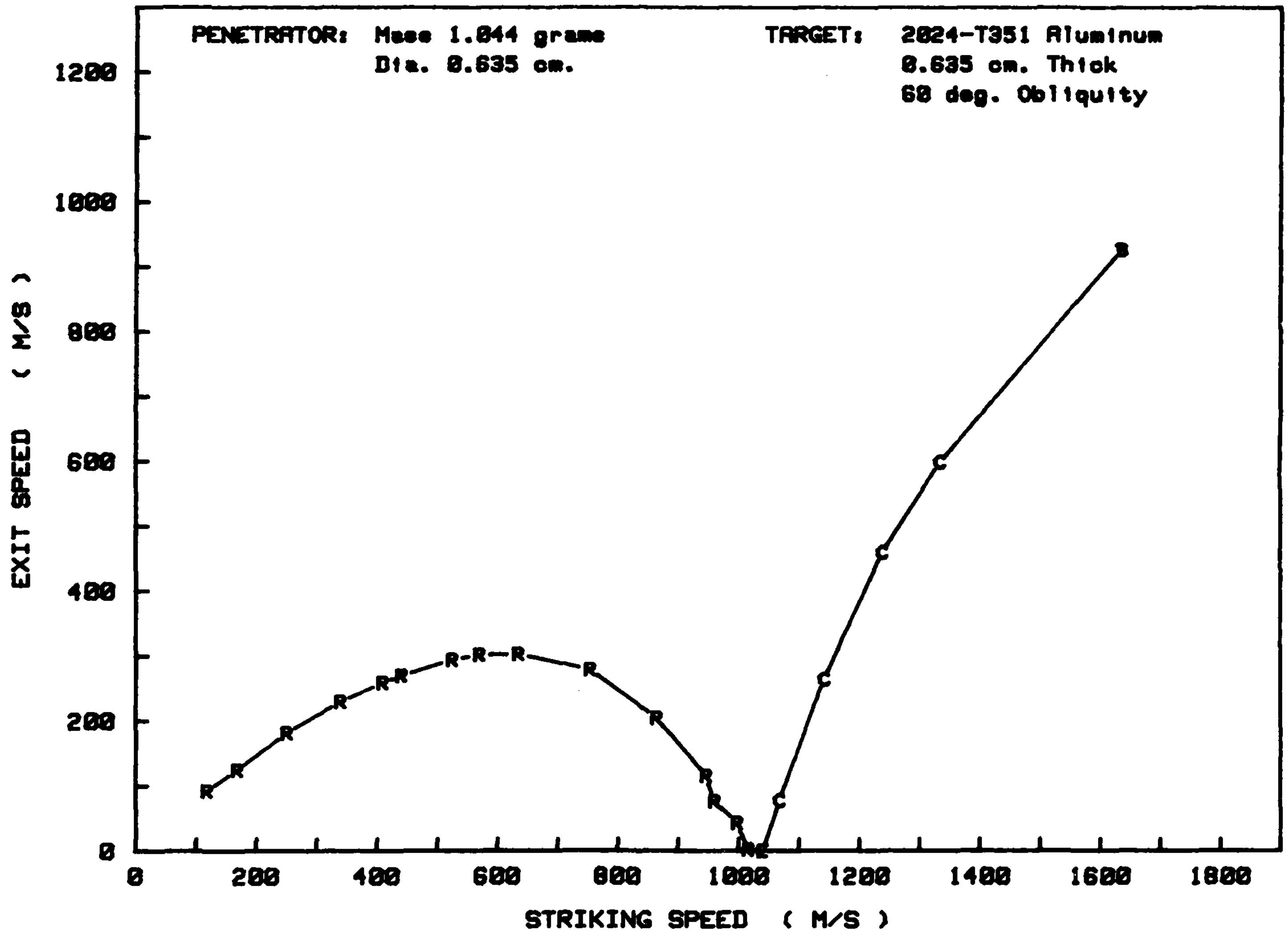


Figure 7a 1/4 in. Steel Sphere Impacting 1/4 Inch Thick Aluminum At 60 Degrees
(Exit Speed As A Function Of Striking Speed)

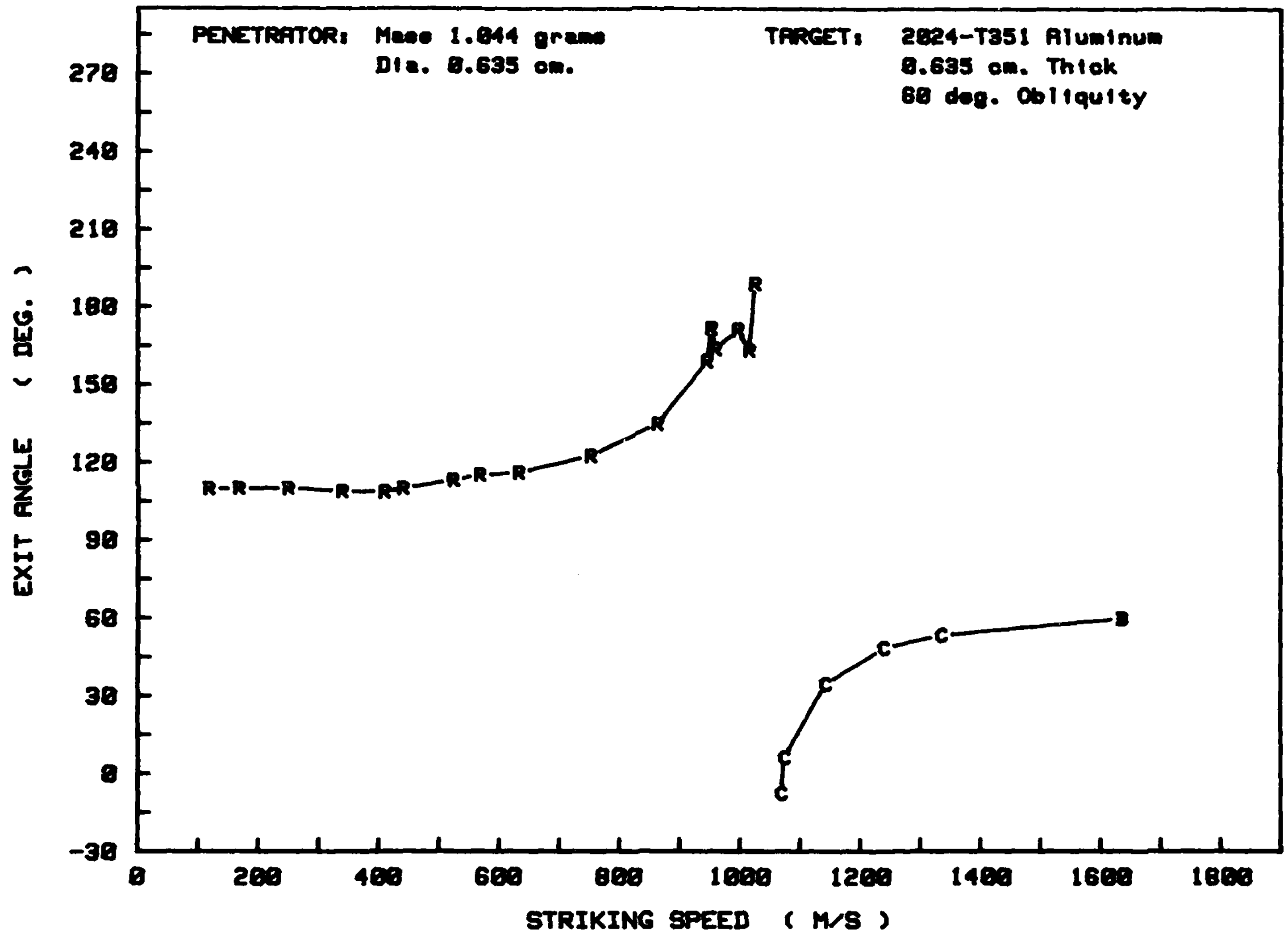


Figure 7b 1/4 in. Steel Sphere Impacting 1/4 Inch Thick Aluminum At 60 Degrees
(Exit Angle As A Function Of Striking Speed)

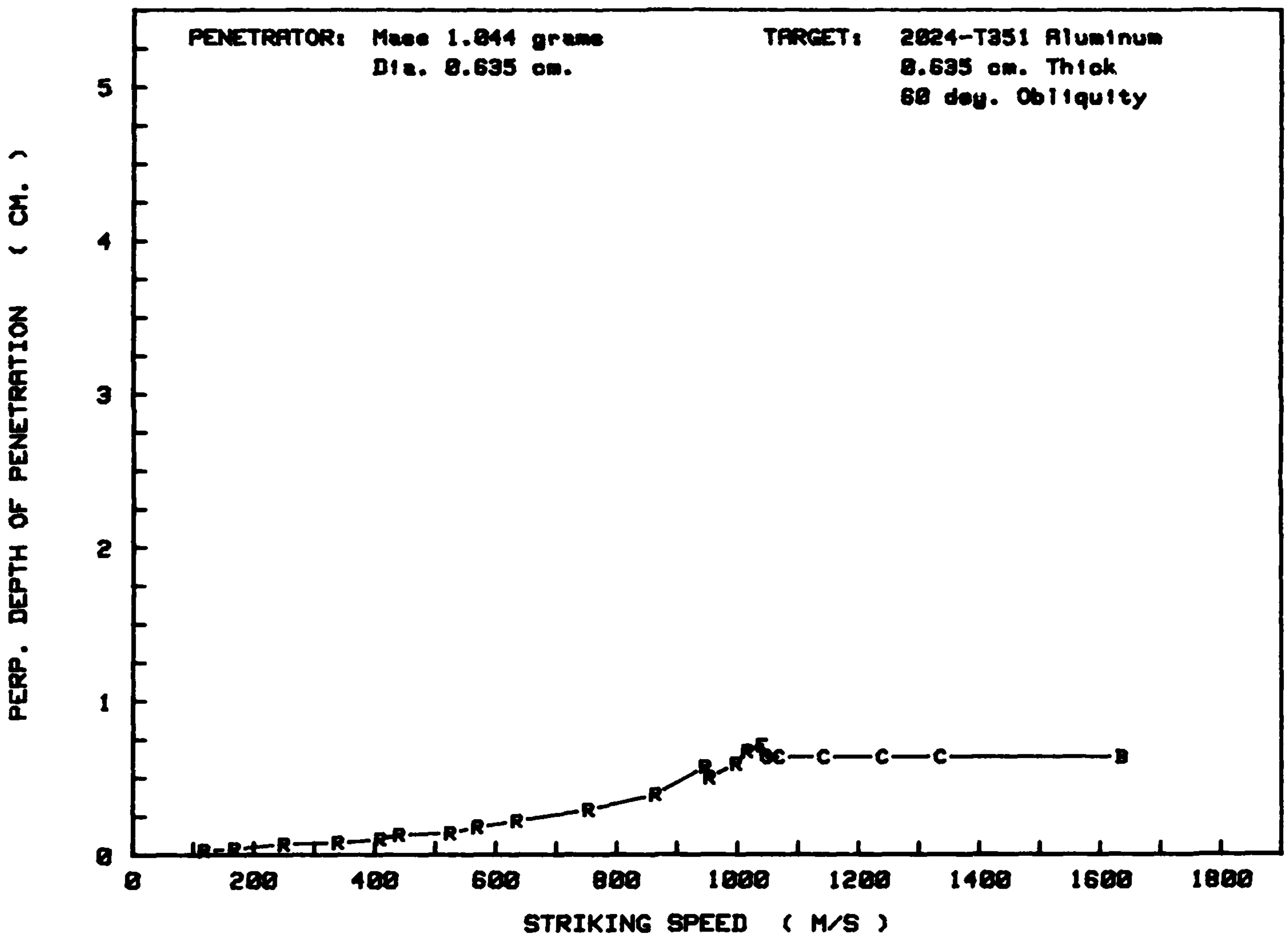


Figure 7c 1/4 in. Steel Sphere Impacting 1/4 Inch Thick Aluminum At 60 Degrees
(Perpendicular Depth As A Function Of Striking Speed)

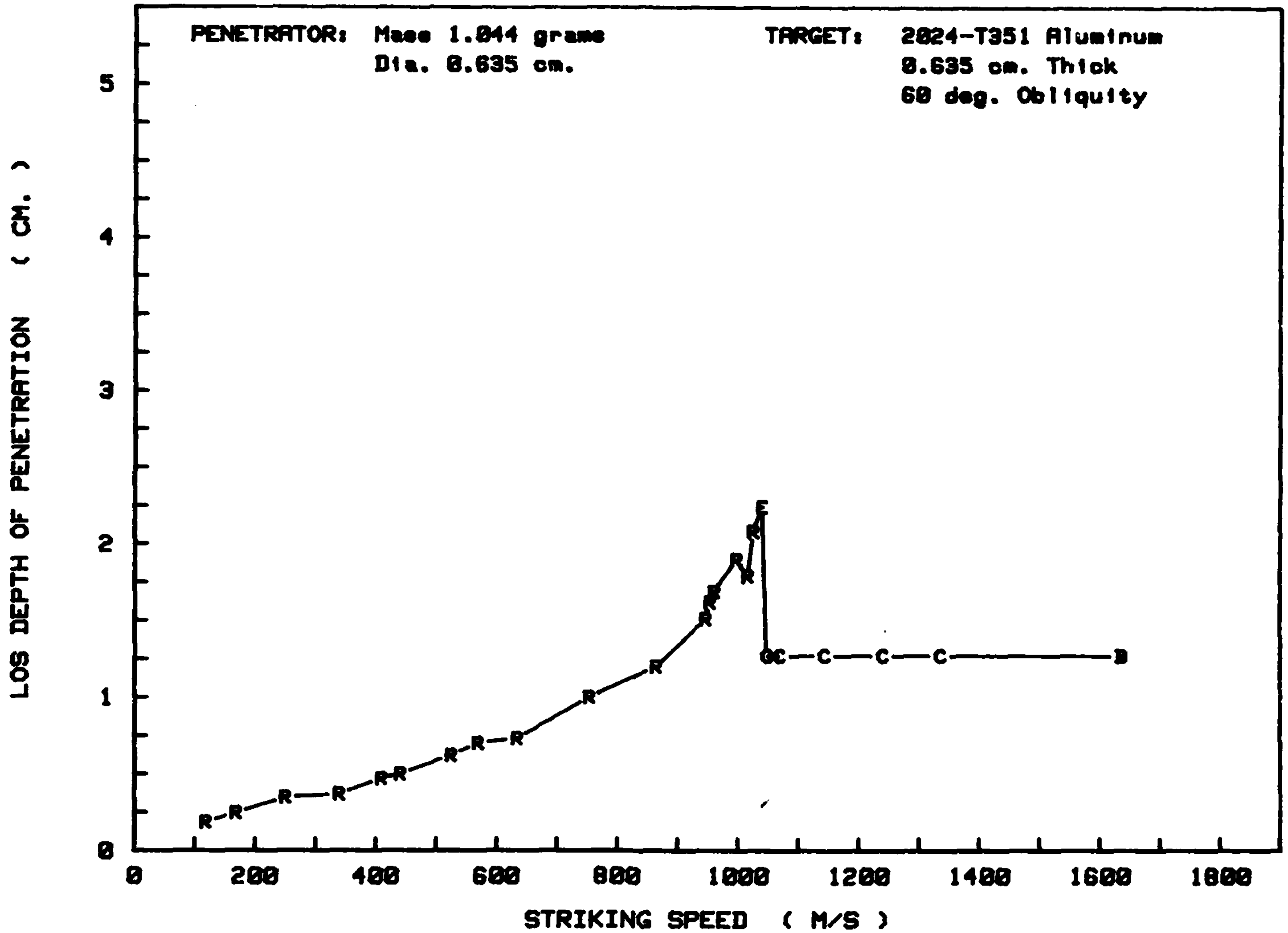


Figure 7d 1/4 in. Steel Sphere Impacting 1/4 Inch Thick Aluminum At 60 Degrees
(Line-of-Sight Depth As A Function Of Striking Speed)

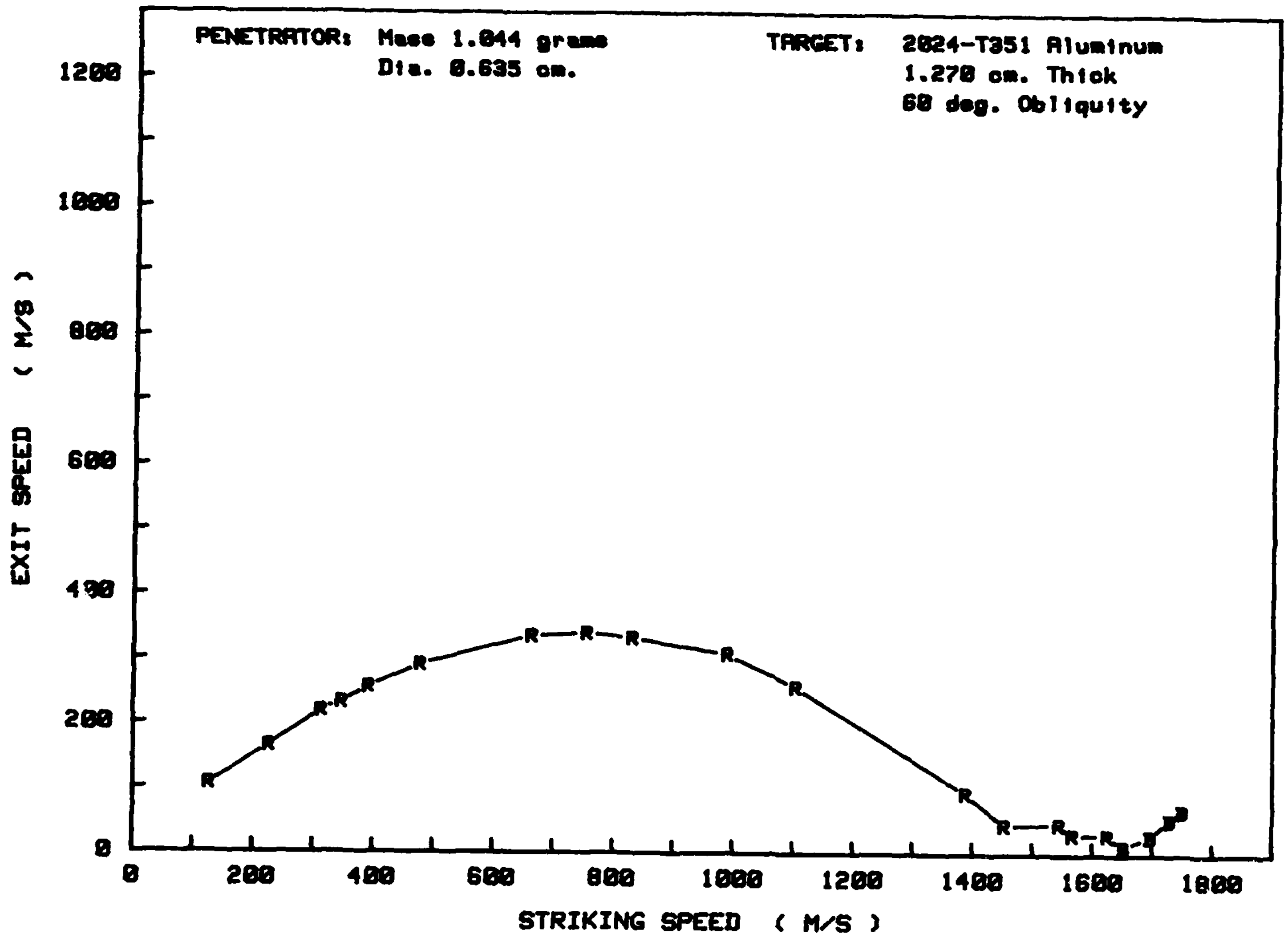


Figure 8a 1/4 in. Steel Sphere Impacting 1/2 Inch Thick Aluminum At 60 Degrees
(Exit Speed As A Function Of Striking Speed)

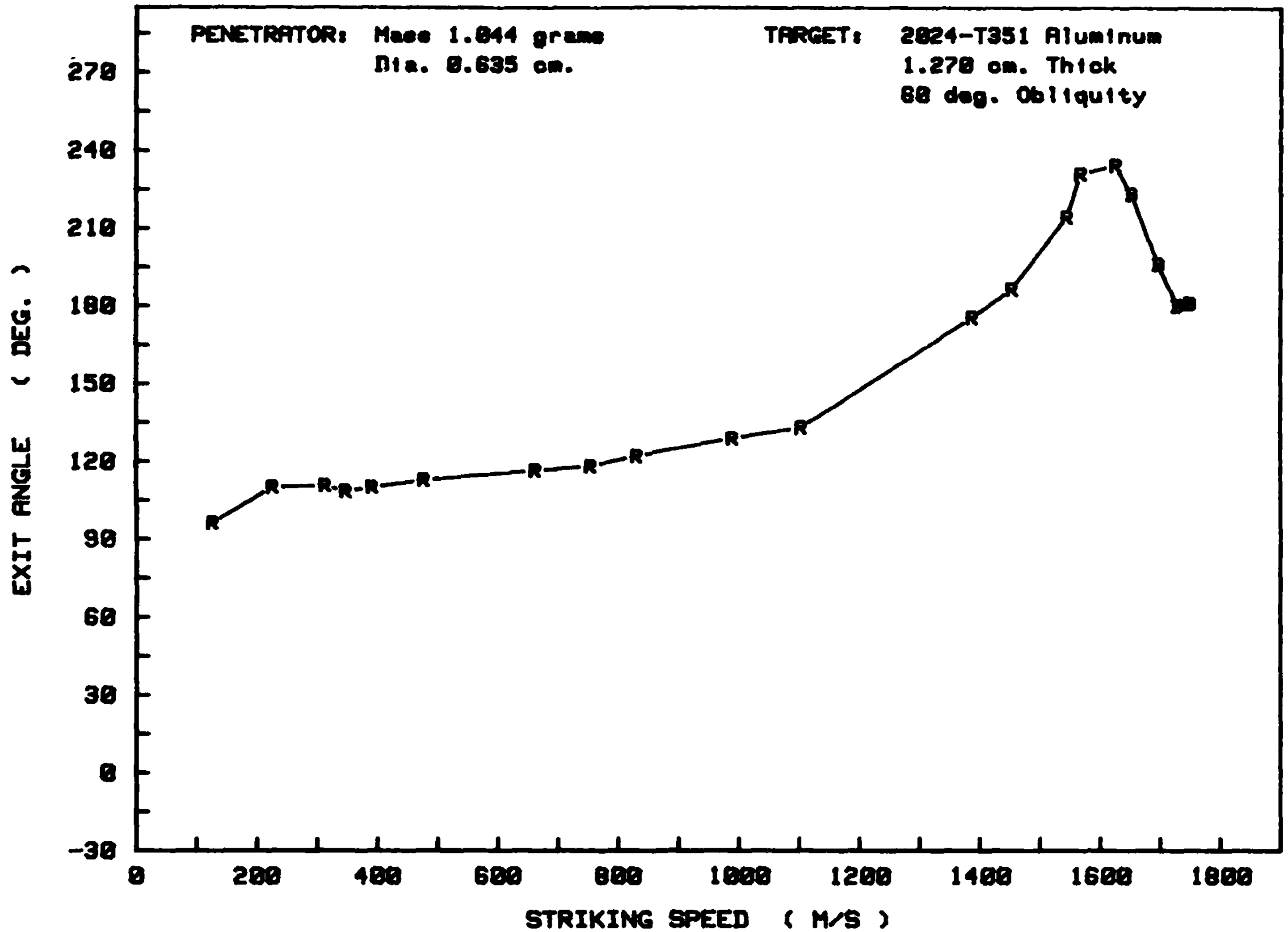


Figure 8b 1/4 in. Steel Sphere Impacting 1/2 Inch Thick Aluminum At 60 Degrees
(Exit Angle As A Function Of Striking Speed)

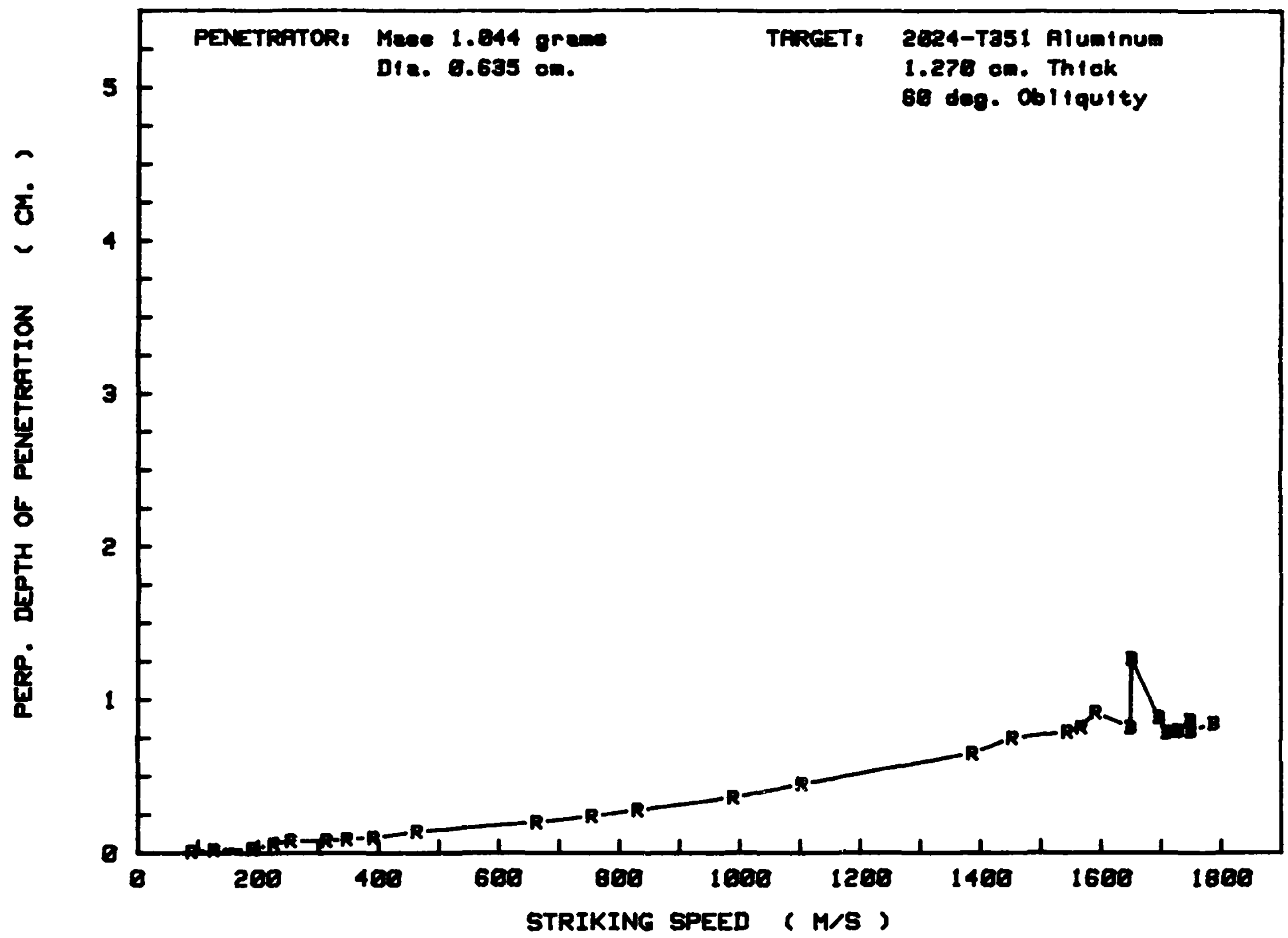


Figure 8c 1/4 in. Steel Sphere Impacting 1/2 Inch Thick Aluminum At 60 Degrees
(Perpendicular Depth As A Function Of Striking Speed)

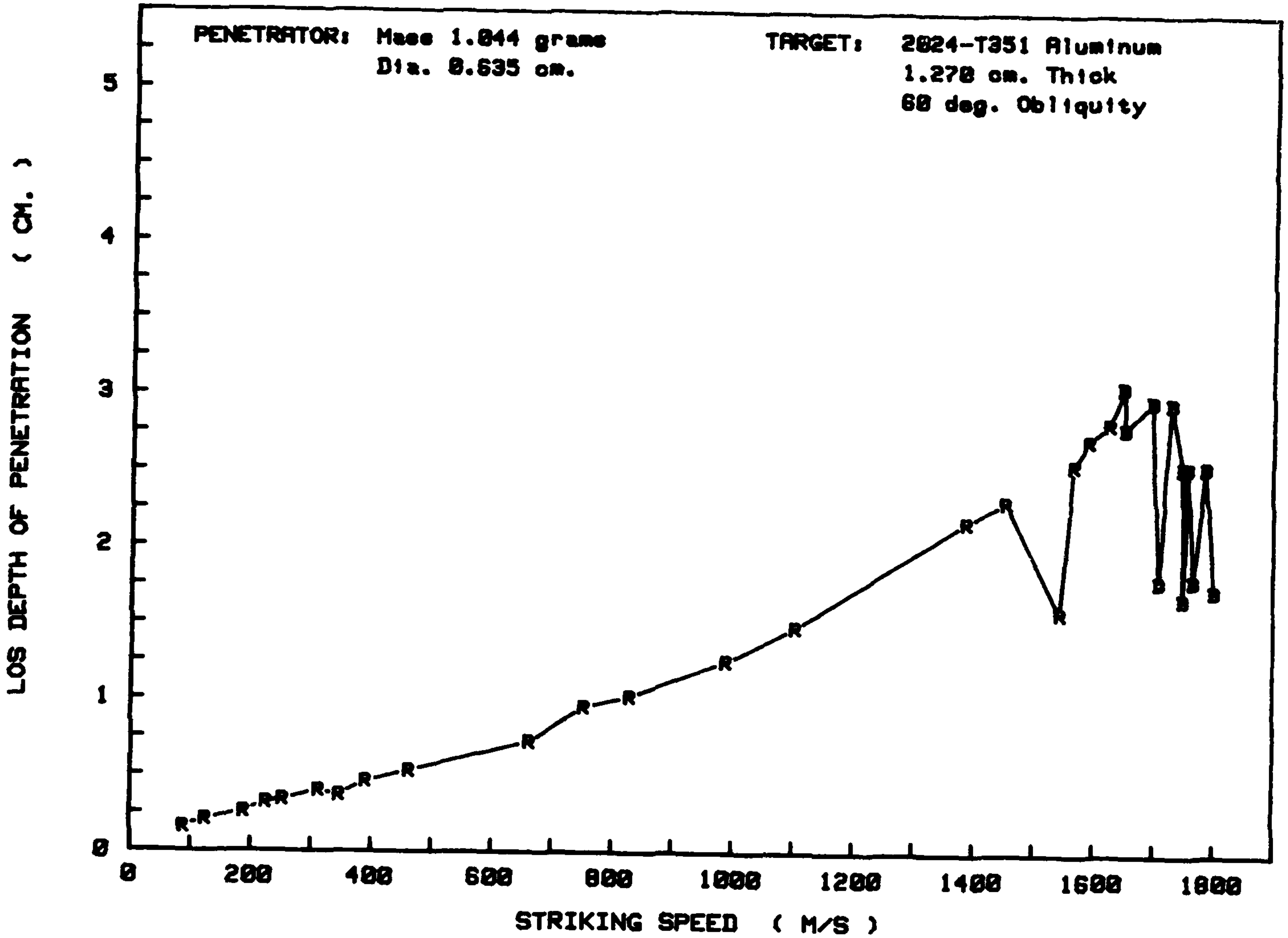


Figure 8d 1/4 in. Steel Sphere Impacting 1/2 Inch Thick Aluminum At 60 Degrees
(Line-of-Sight Depth As A Function Of Striking Speed)

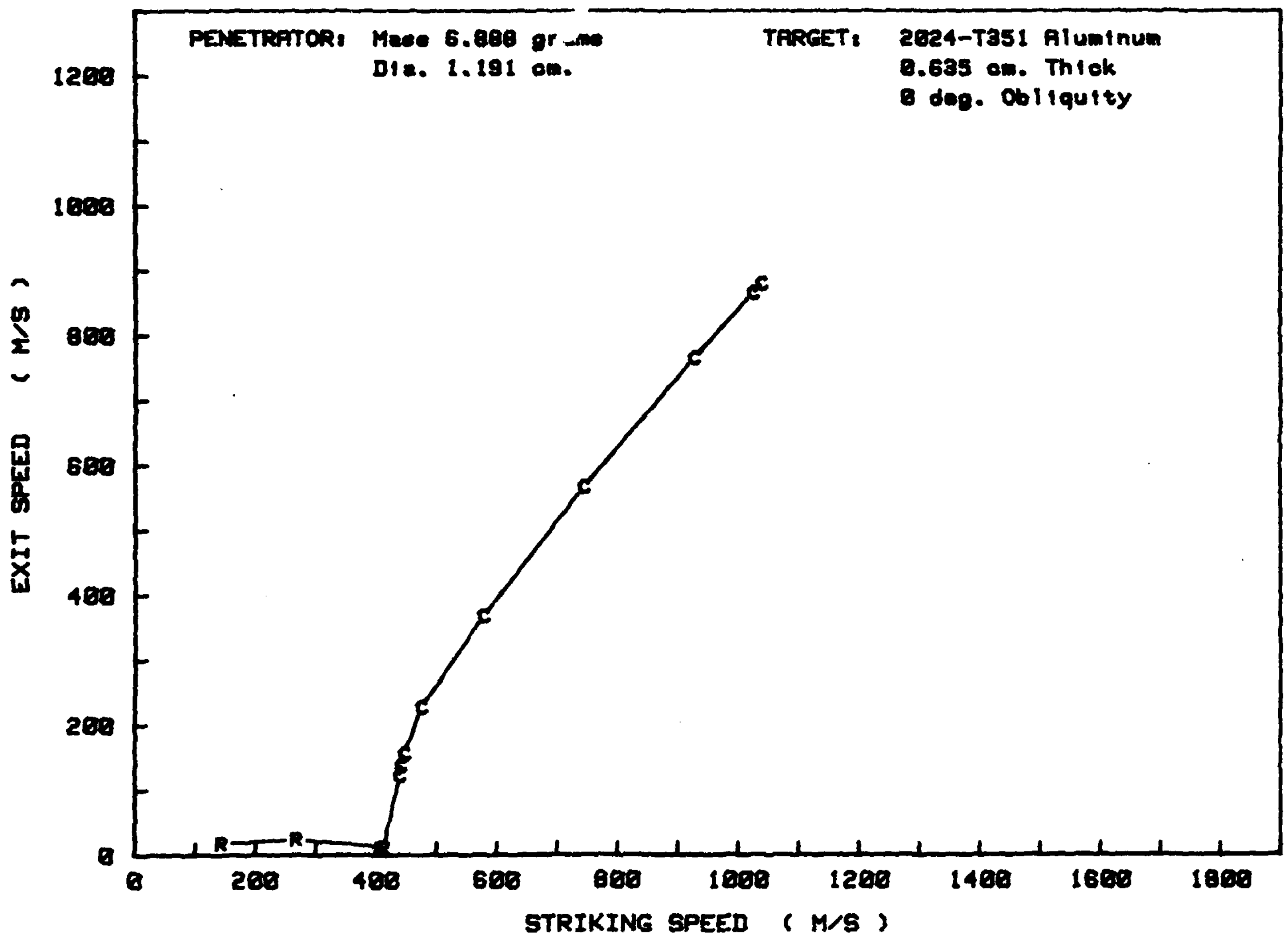


Figure 9a 15/32 in. Steel Sphere Impacting 1/4 in. Thick Aluminum At 0 Degrees
(Exit Speed As A Function Of Striking Speed)

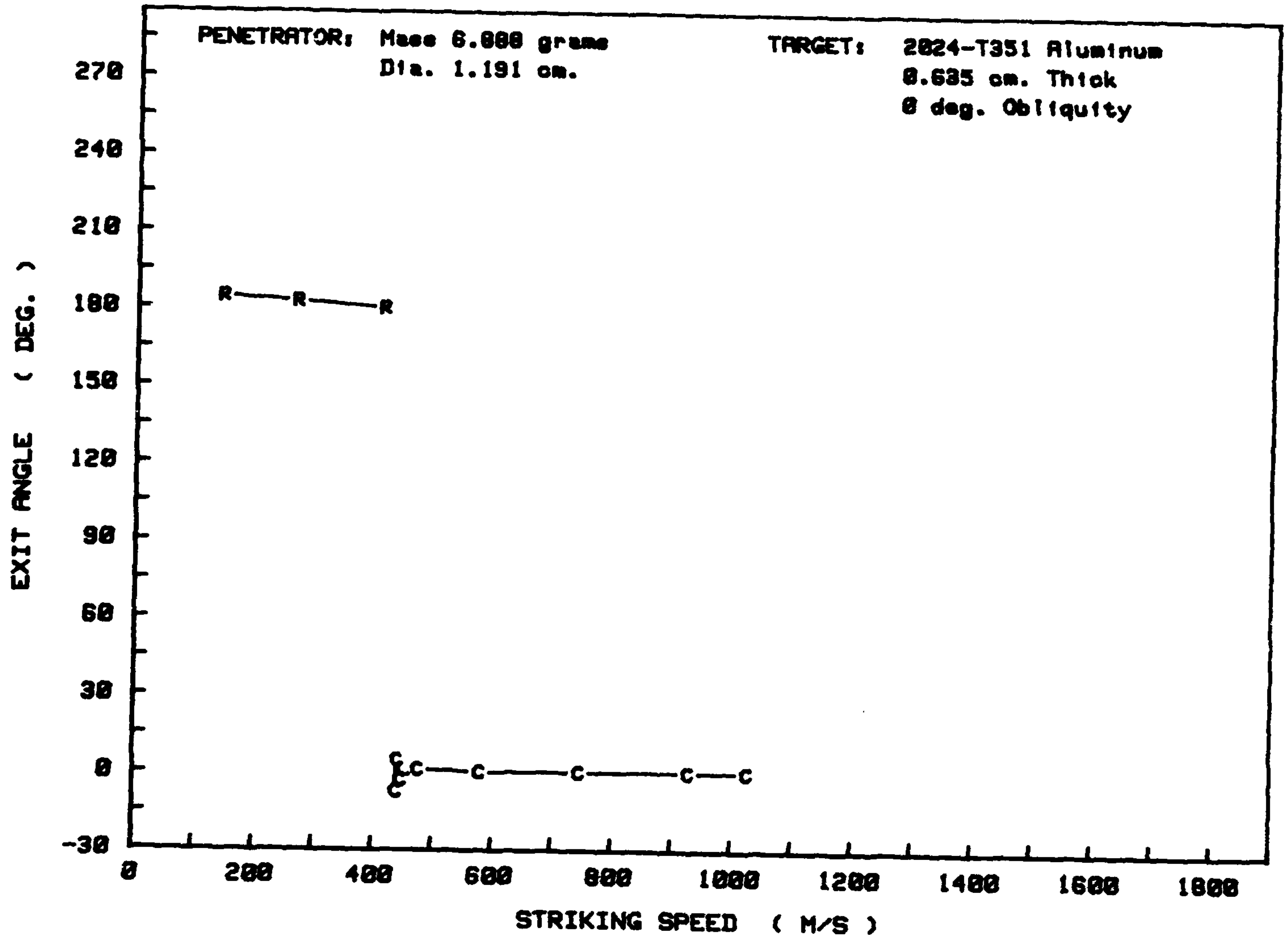


Figure 9b 15/32 in. Steel Sphere Impacting 1/4 in. Thick Aluminum At 0 Degrees (Exit Angle As A Function Of Striking Speed)

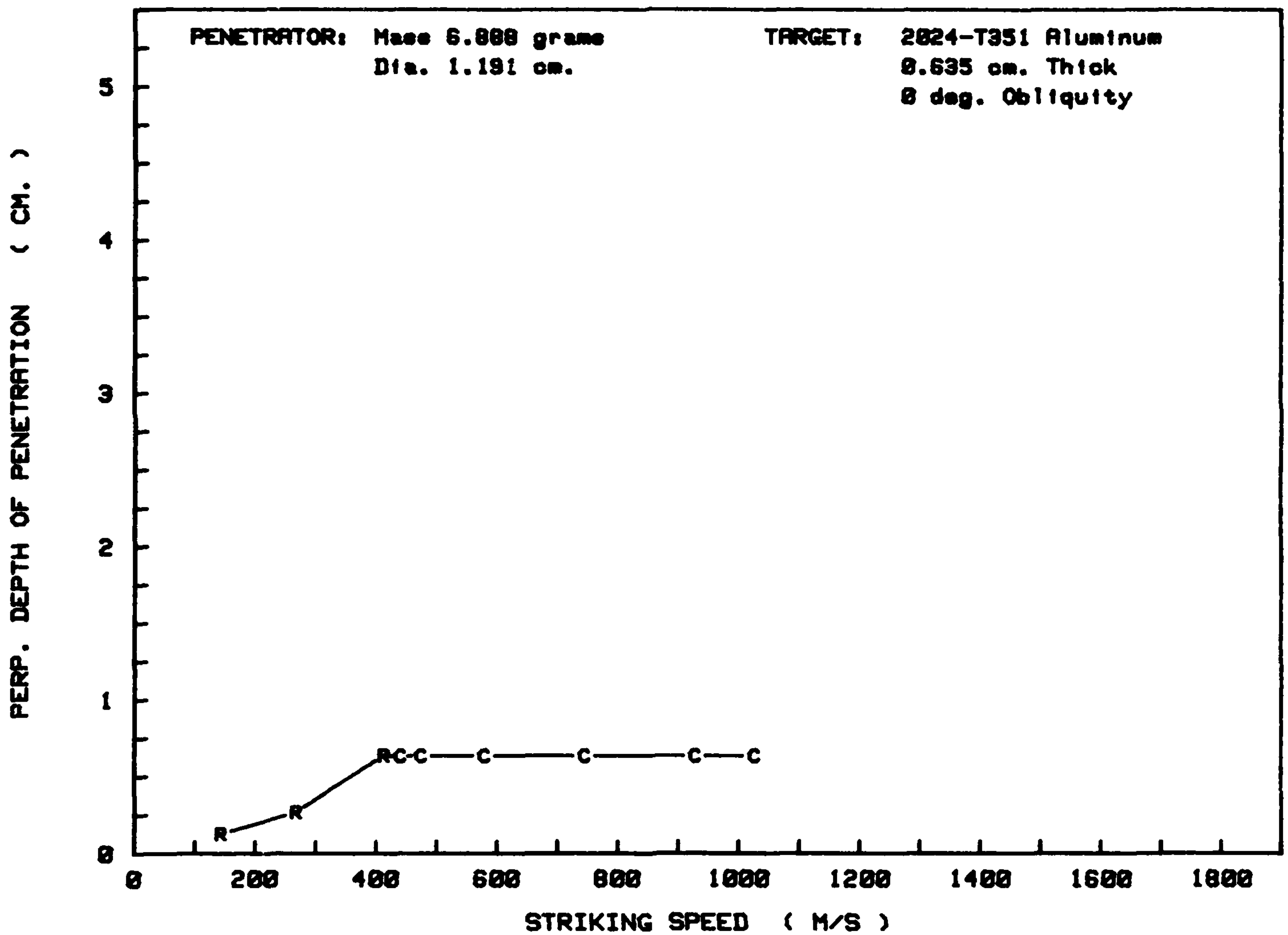


Figure 9c 15/32 in. Steel Sphere Impacting 1/4 in. Thick Aluminum At 0 Degrees
(Perpendicular Depth As A Function Of Striking Speed)

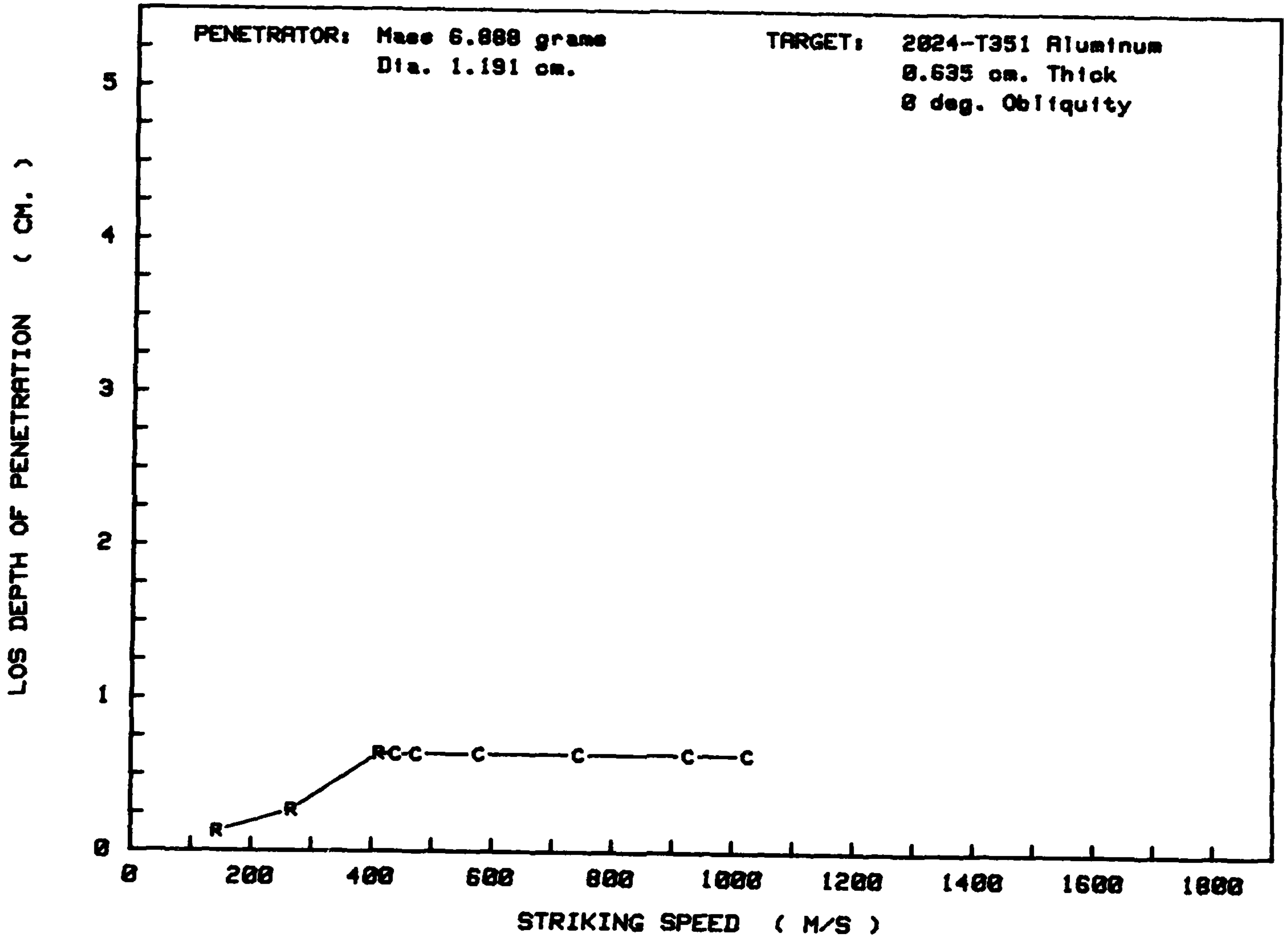


Figure 9d 15/32 in. Steel Sphere Impacting 1/4 in. Thick Aluminum At 0 Degrees (Line-of-Sight Depth As A Function Of Striking Speed)

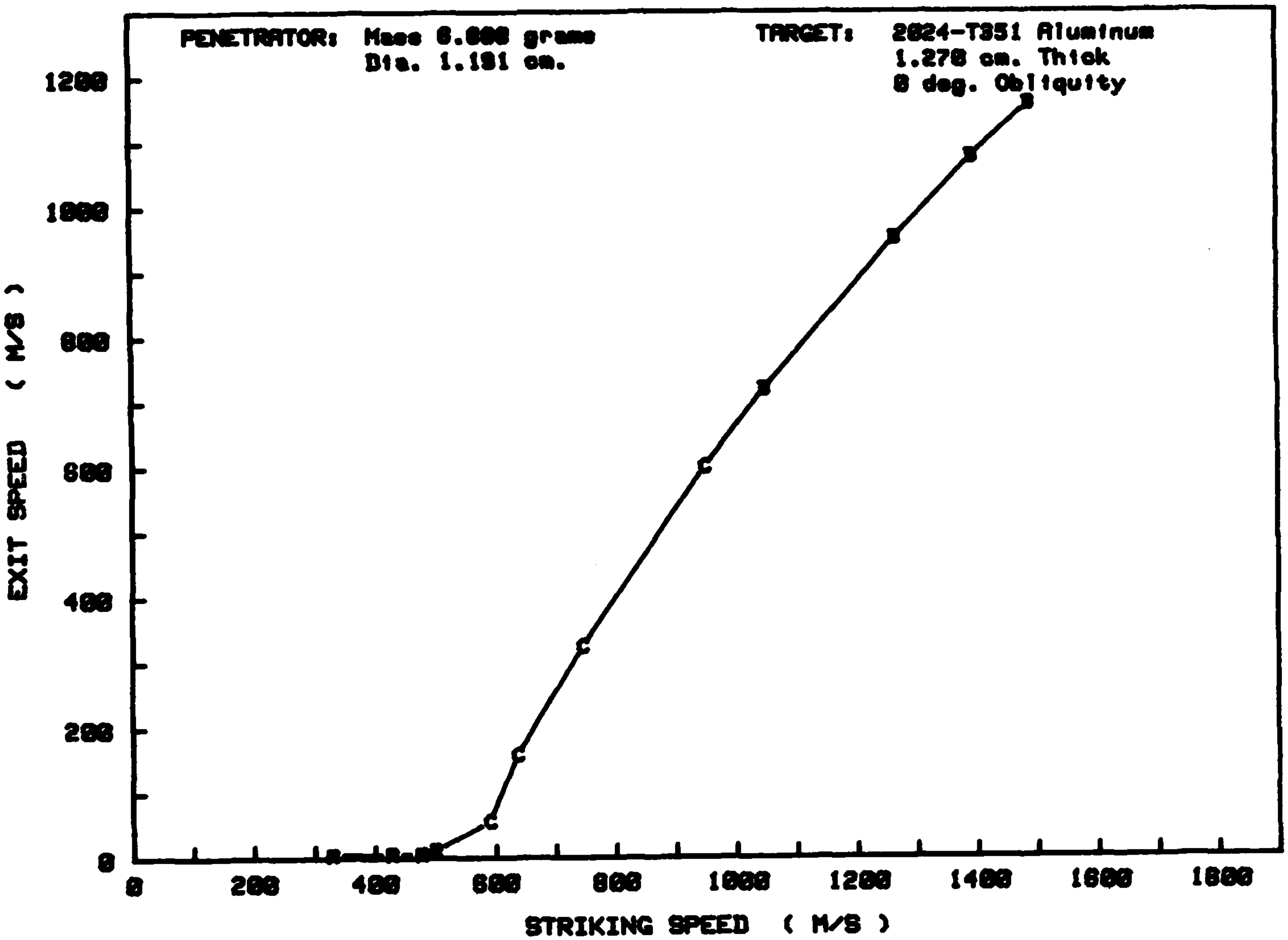


Figure 10a 15/32 in. Steel Sphere Impacting 1/2 in. Thick Aluminum At 0 Degrees
(Exit Speed As A Function Of Striking Speed)

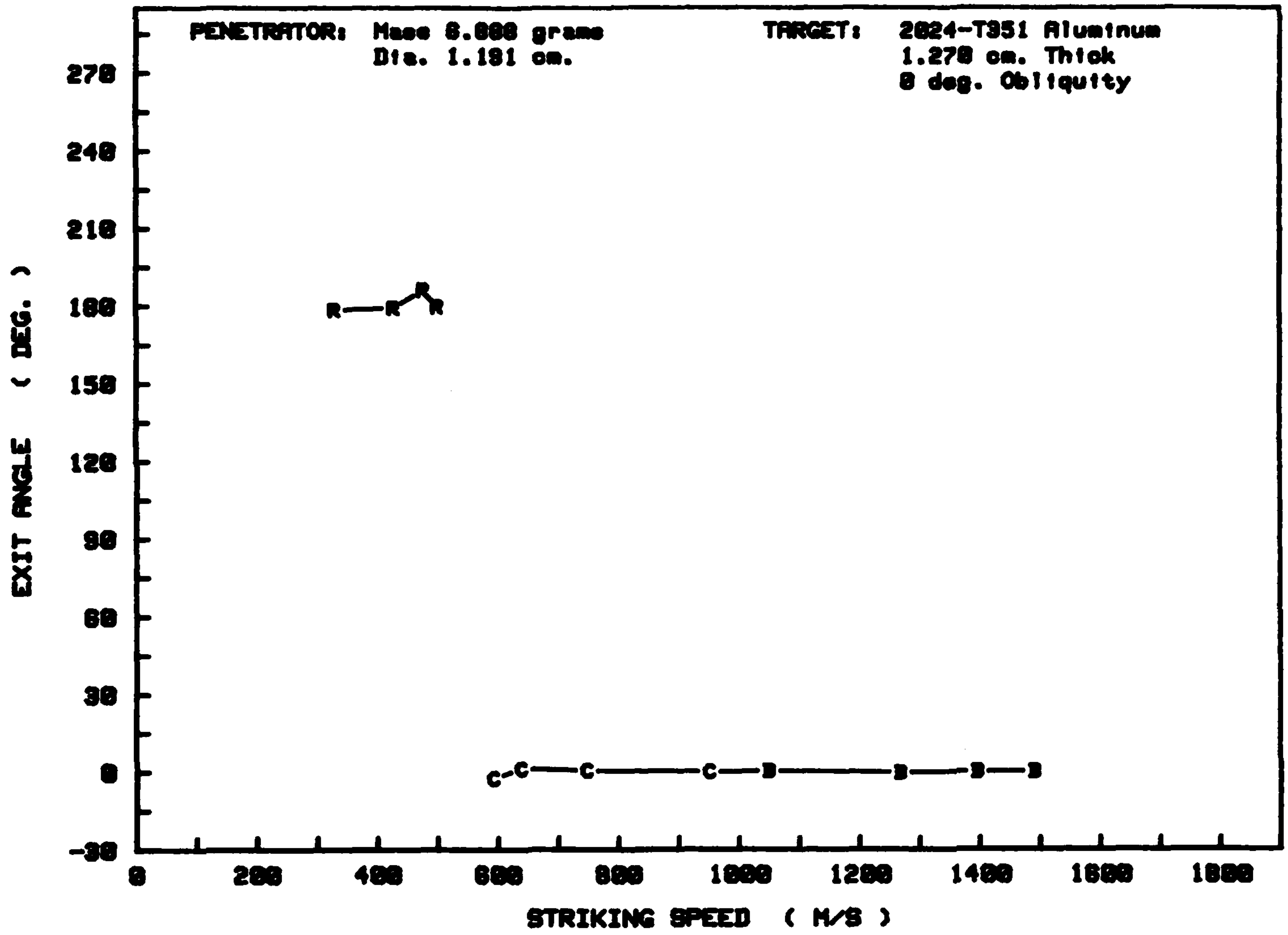


Figure 10b 15/32 in. Steel Sphere Impacting 1/2 in. Thick Aluminum At 0 Degrees
(Exit Angle As A Function Of Striking Speed)

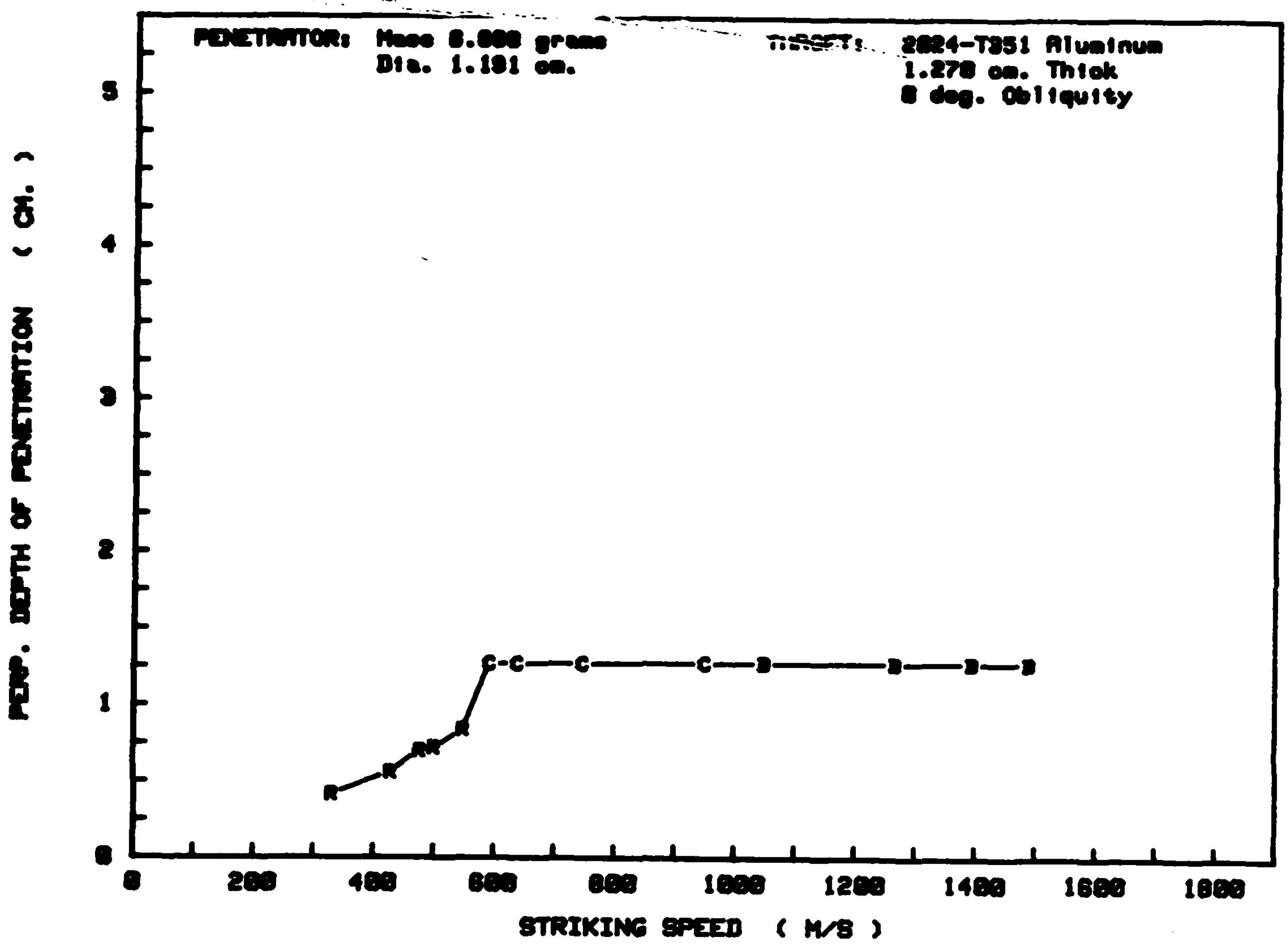


Figure 10c 15/32 in. Steel Sphere Impacting 1/2 in. Thick Aluminum At 0 Degrees
(Perpendicular Depth As A Function Of Striking Speed)

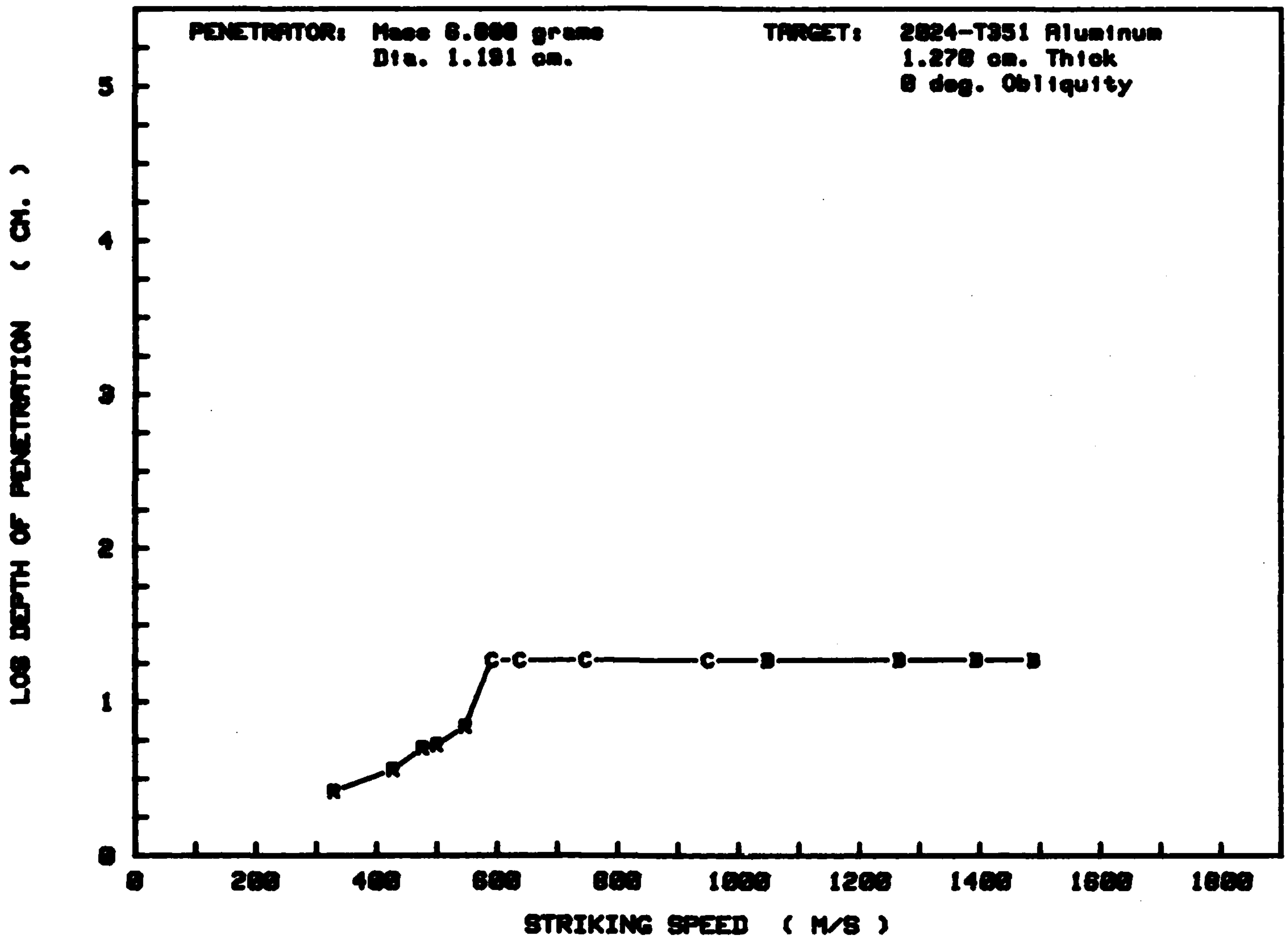


Figure 10d 15/32 in. Steel Sphere Impacting 1/2 in. Thick Aluminum At 0 Degrees
(Line-of-Sight Depth As A Function Of Striking Speed)

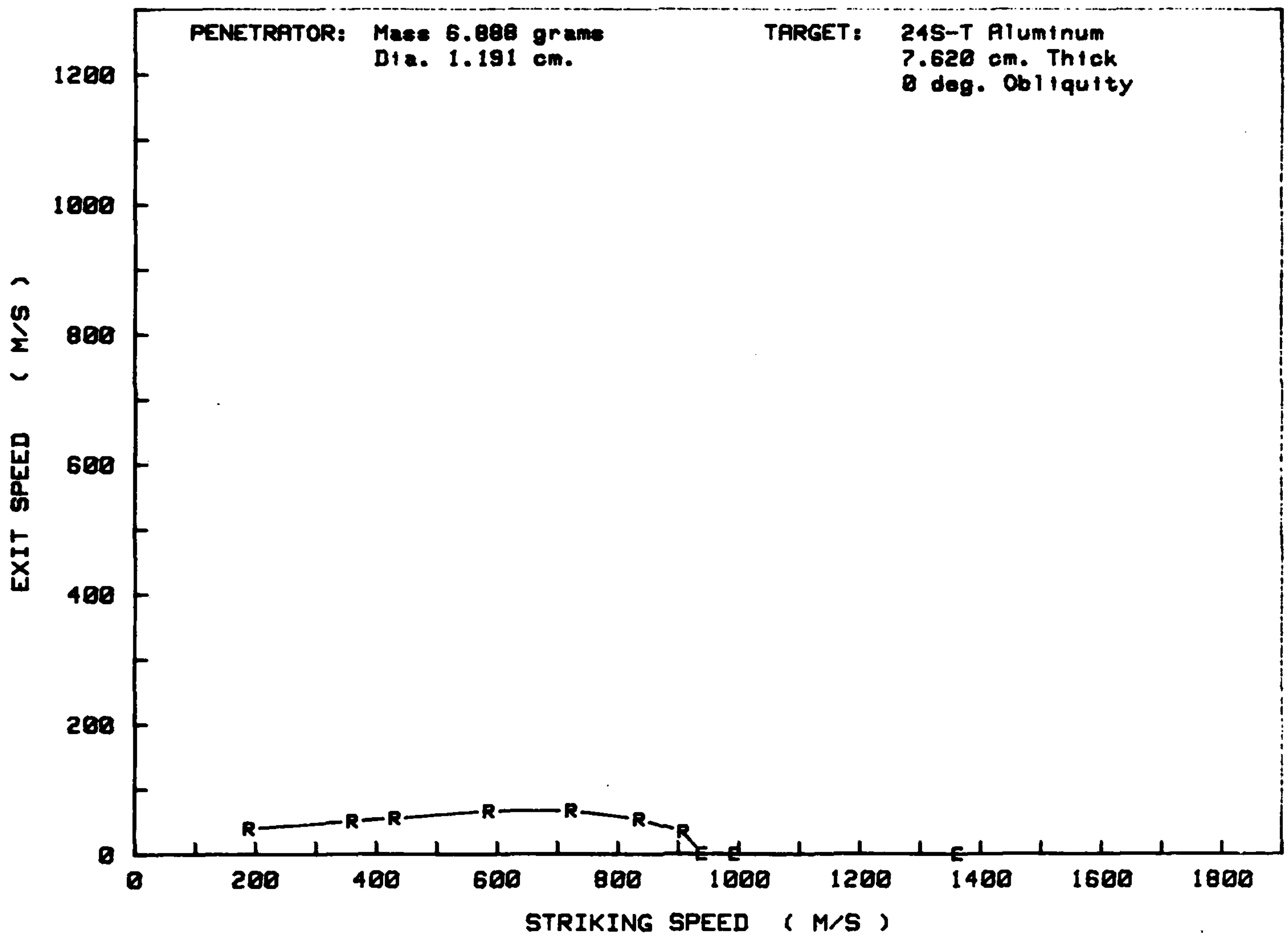


Figure 11a 15/32 in. Steel Sphere Impacting 3 in. Thick Aluminum At 0 Degrees
(Exit Speed As A Function Of Striking Speed)

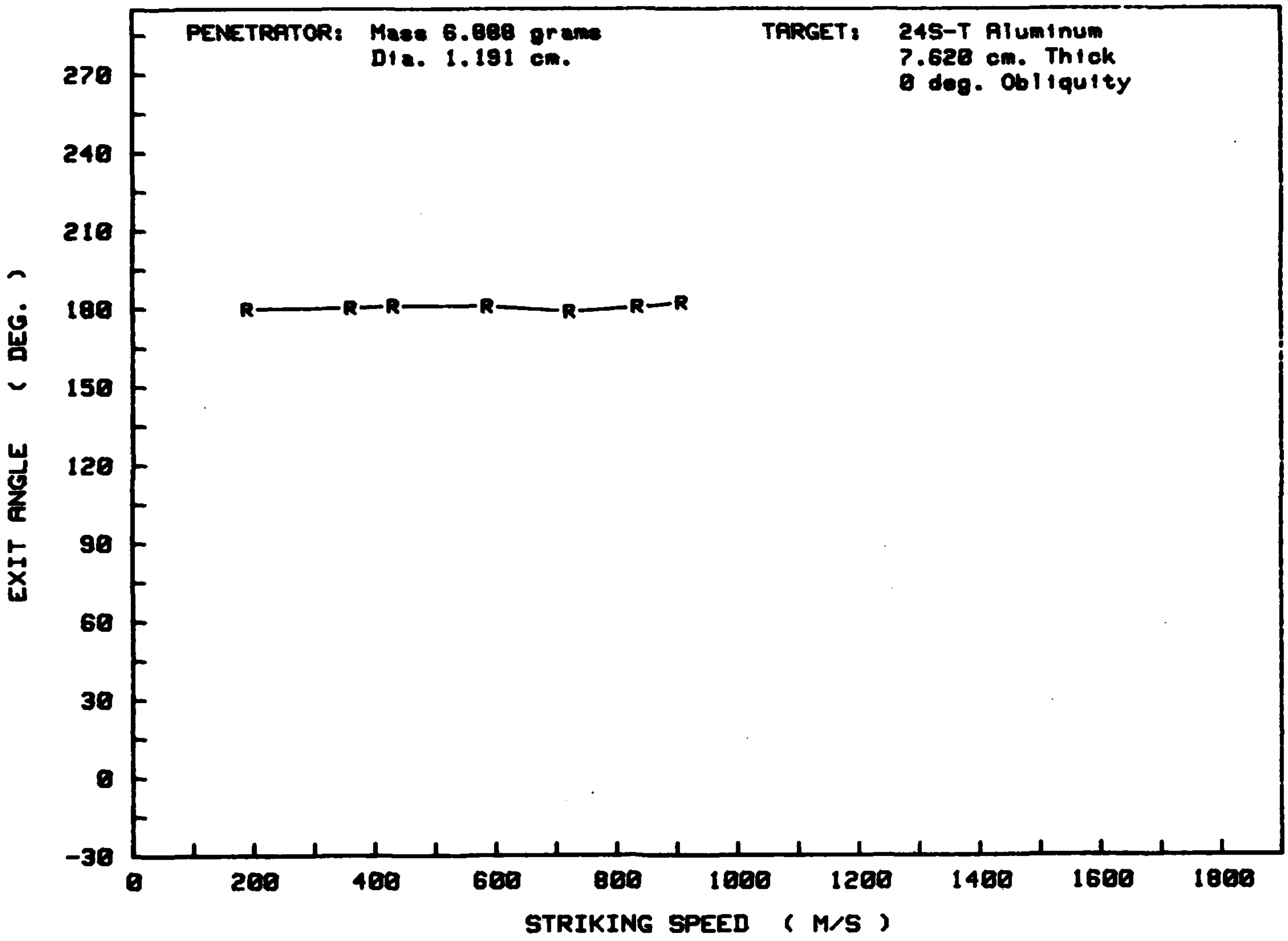


Figure 11b 15/32 in. Steel Sphere Impacting 3 in. Thick Aluminum At 0 Degrees
(Exit Angle As A Function Of Striking Speed)

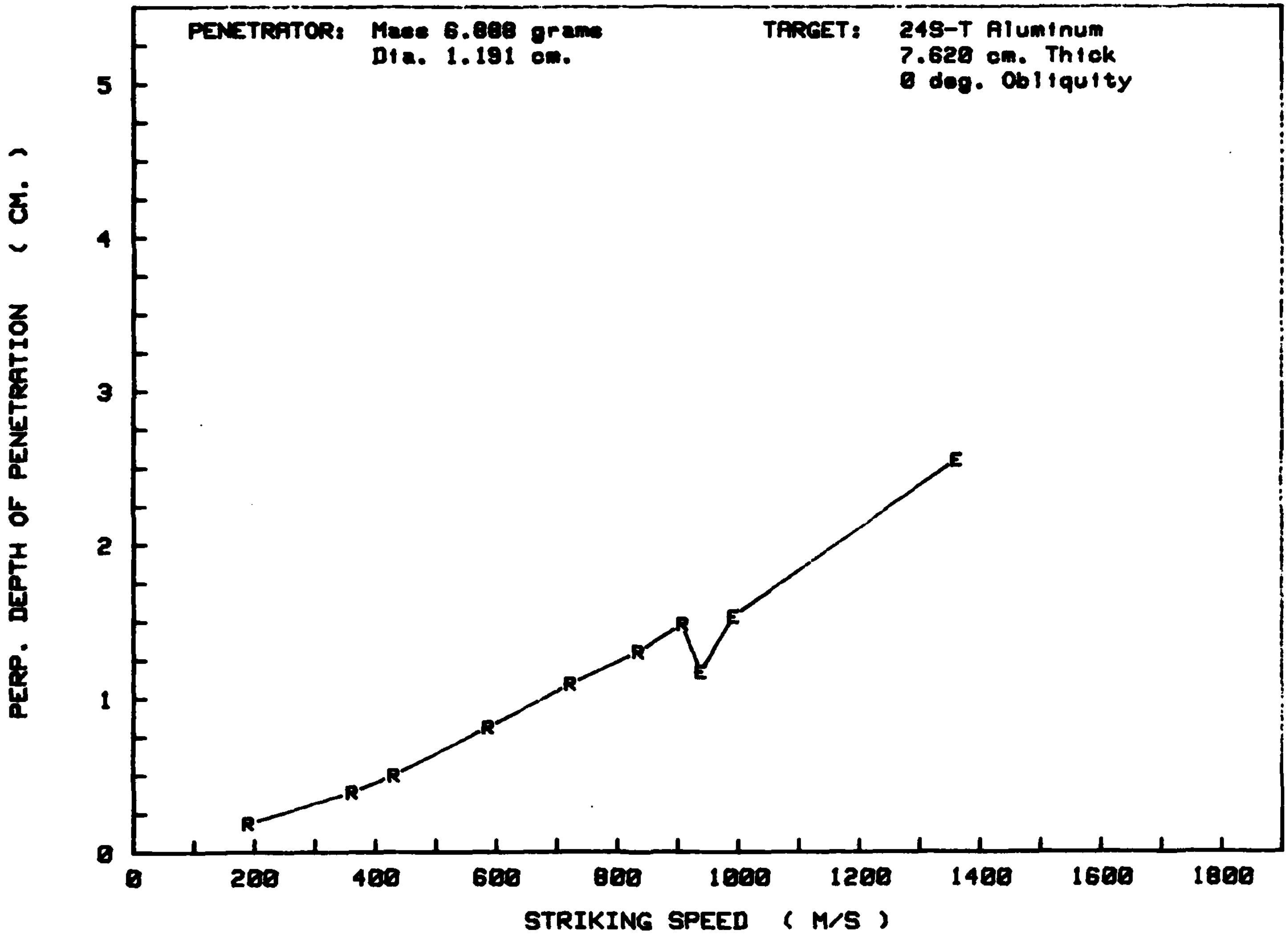


Figure 11c 15/32 in. Steel Sphere Impacting 3 in. Thick Aluminum At 0 Degrees
(Perpendicular Depth As A Function Of Striking Speed)

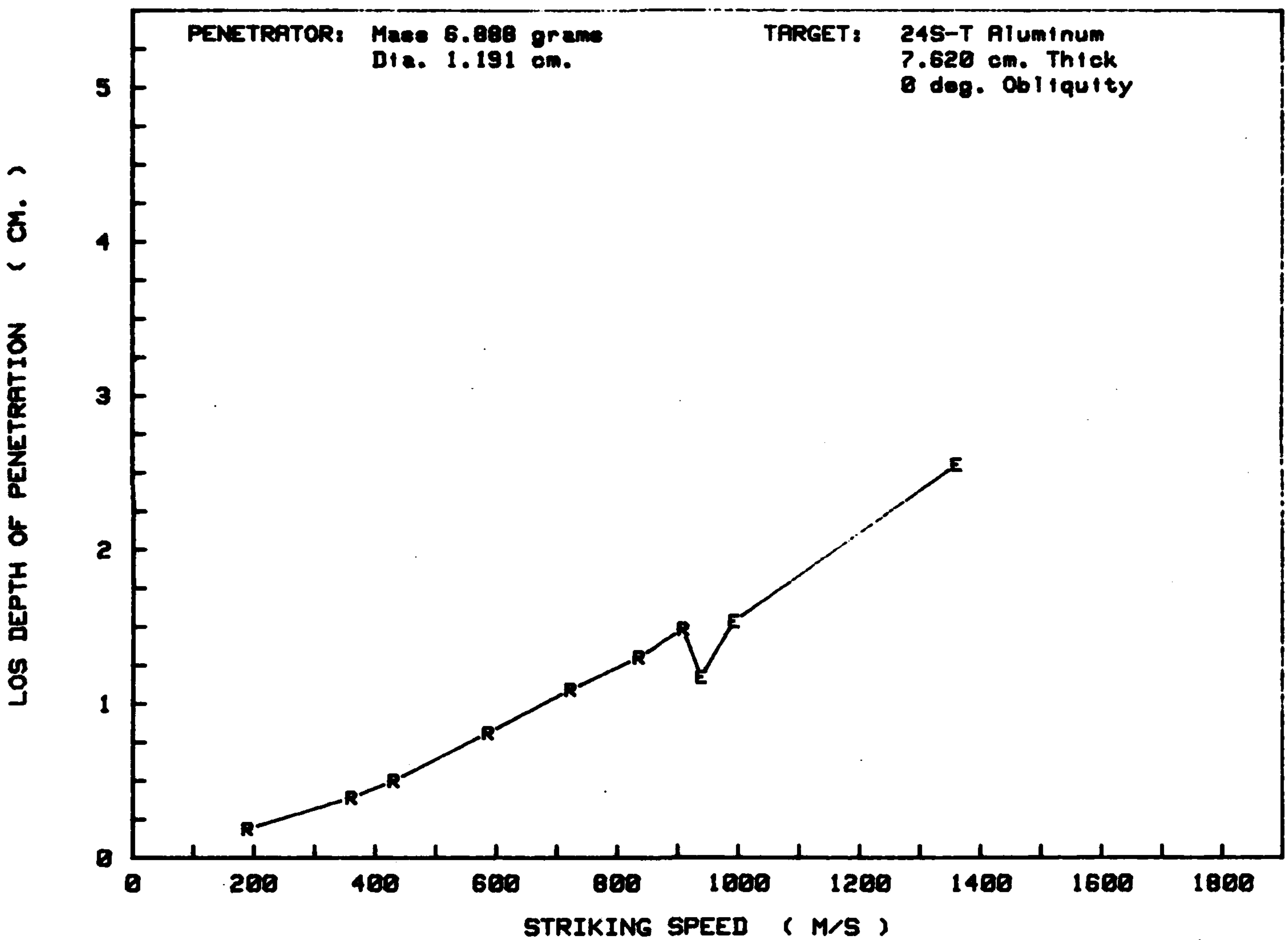


Figure 11d 15/32 in. Steel Sphere Impacting 3 in. Thick Aluminum At 0 Degrees
(Line-of-Sight Depth As A Function Of Striking Speed)

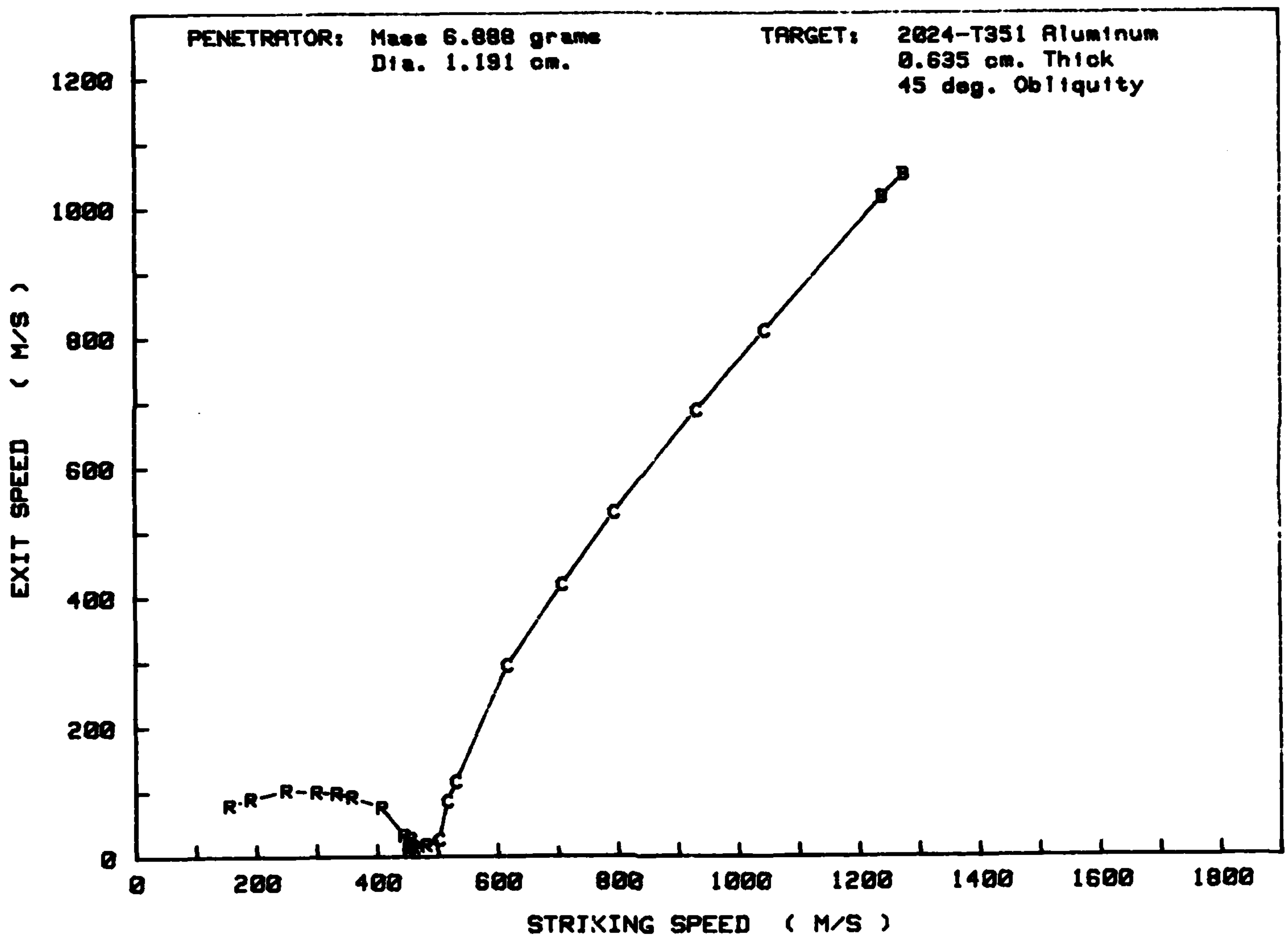


Figure 12a 15/32 in. Steel Sphere Impacting 1/4 in. Thick Aluminum At 45 Degrees
(Exit Speed As A Function Of Striking Speed)

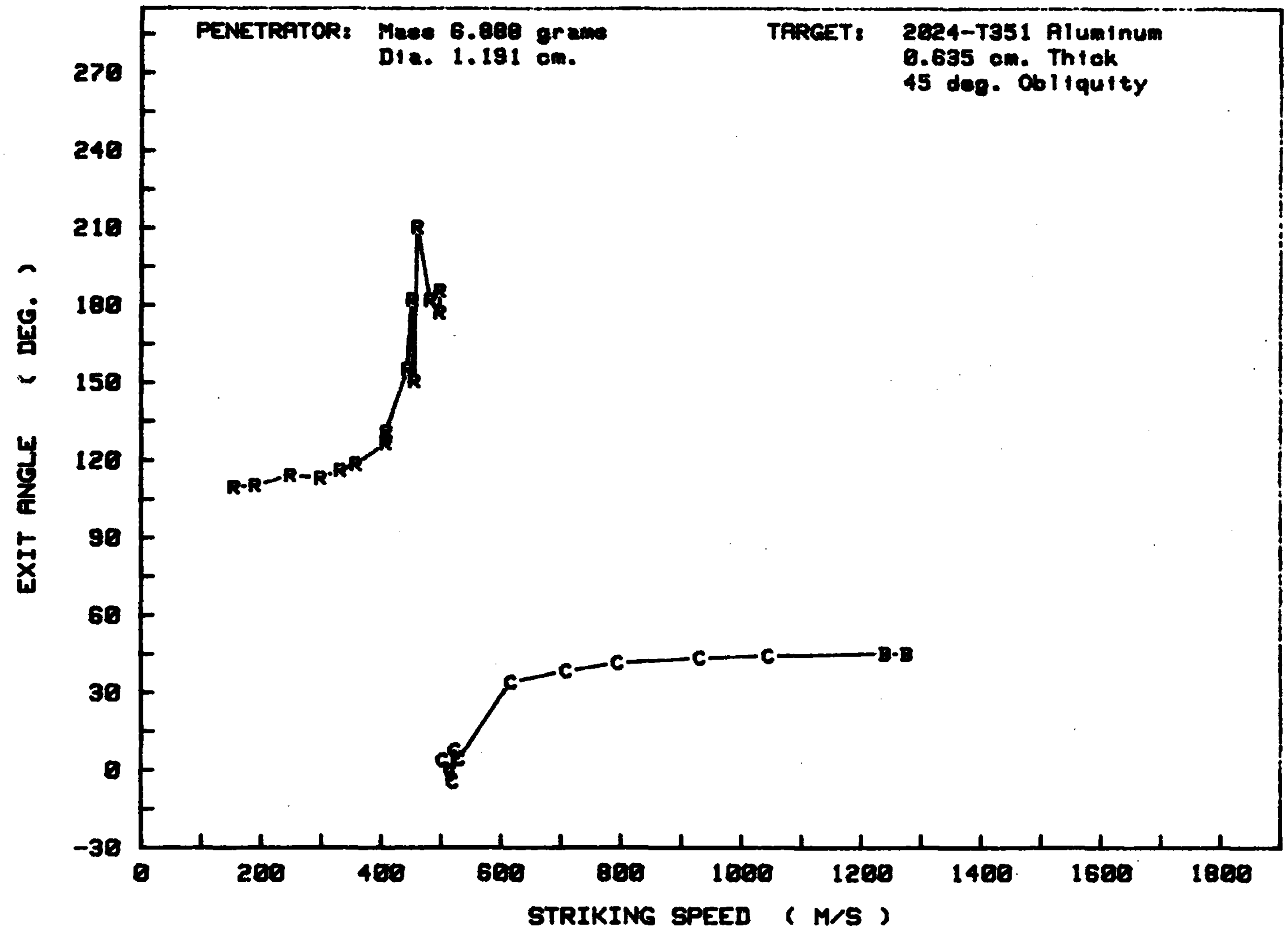


Figure 12b 15/32 in. Steel Sphere Impacting 1/4 in. Thick Aluminum At 45 Degrees
(Exit Angle As A Function Of Striking Speed)

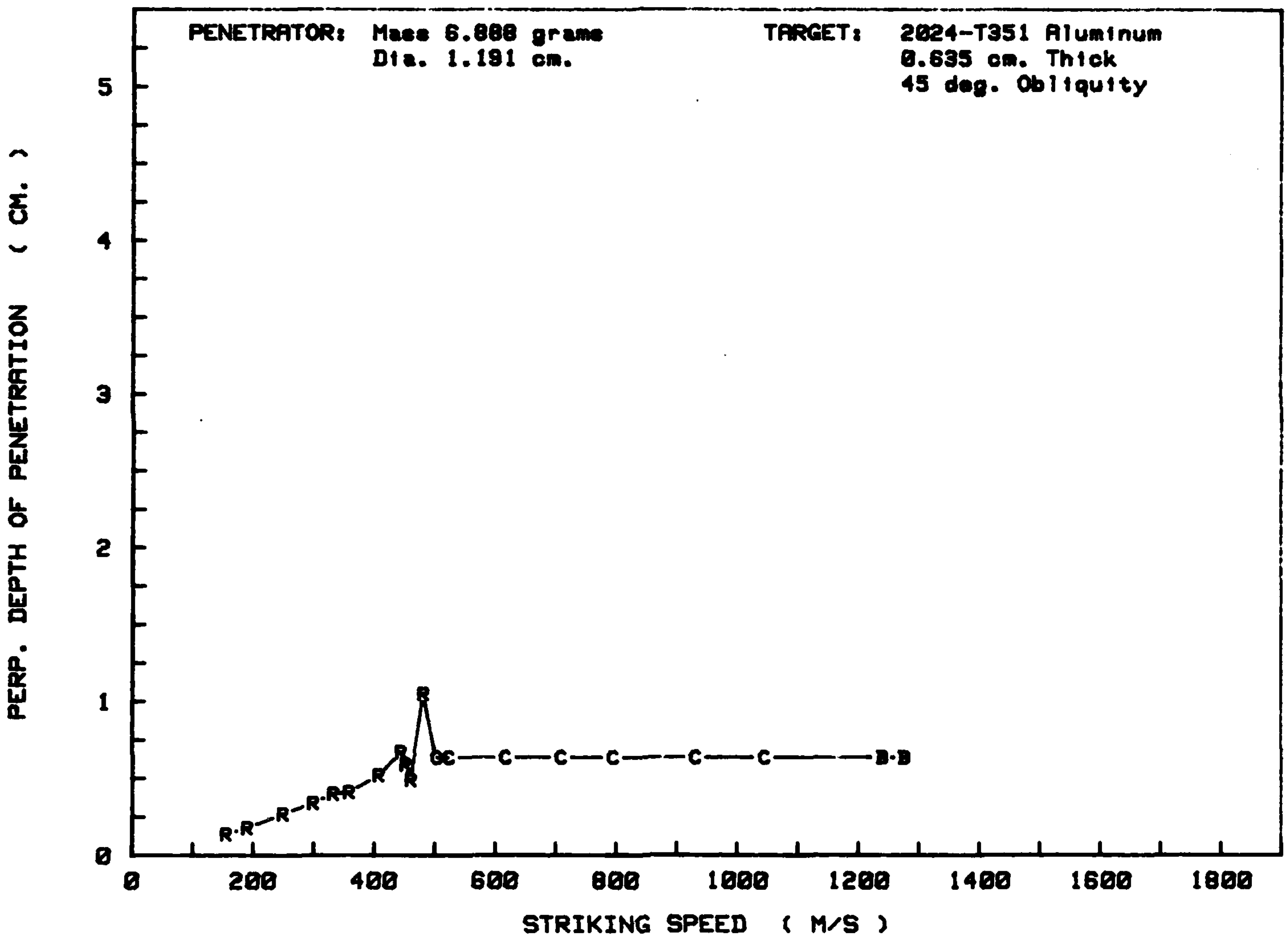


Figure 12c 15/32 in. Steel Sphere Impacting 1/4 in. Thick Aluminum At 45 Degrees
(Perpendicular Depth As A Function Of Striking Speed)

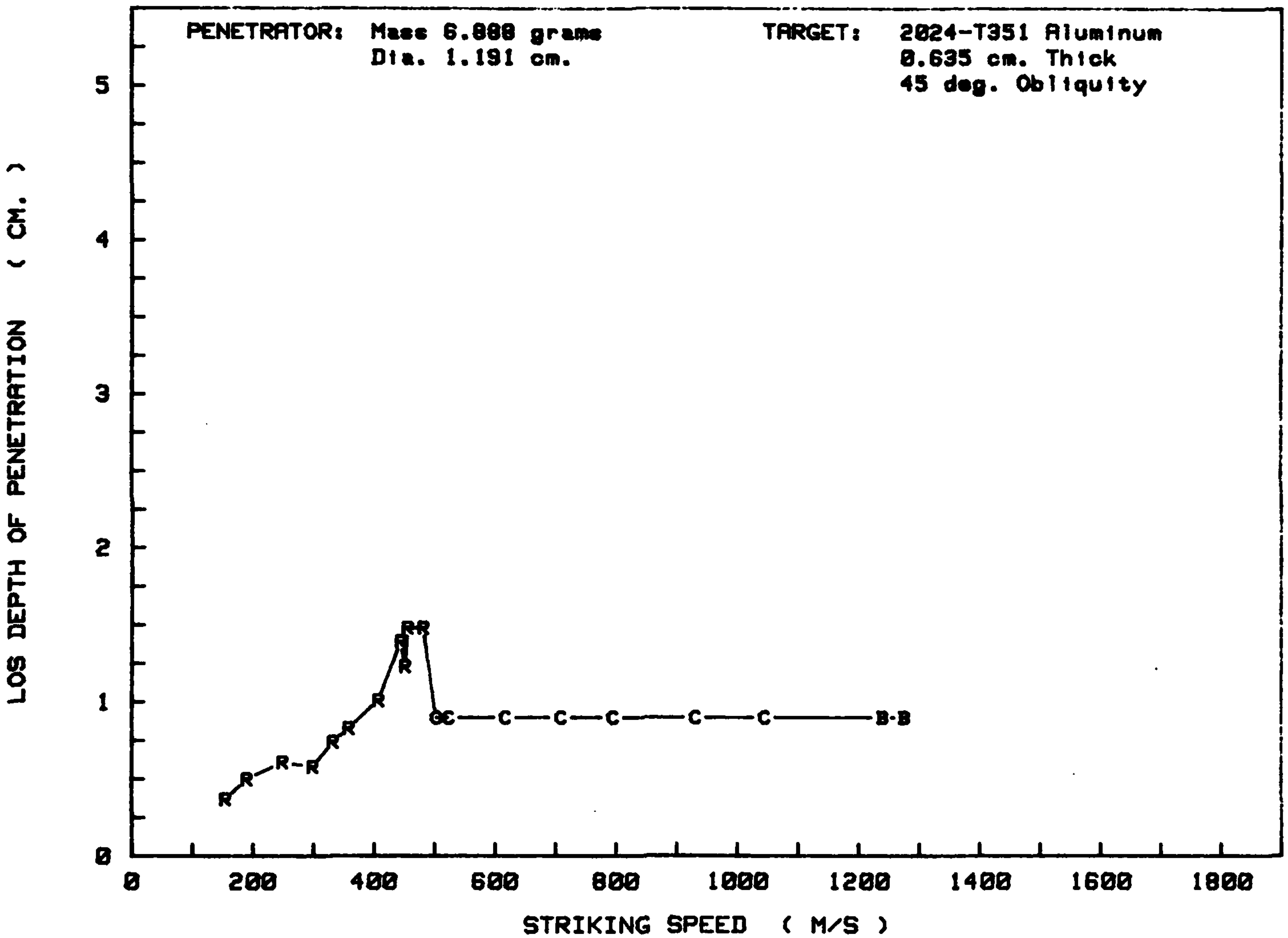


Figure 12d 15/32 in. Steel Sphere Impacting 1/4 in. Thick Aluminum At 45 Degrees
(Line-of-Sight Depth As A Function Of Striking Speed)

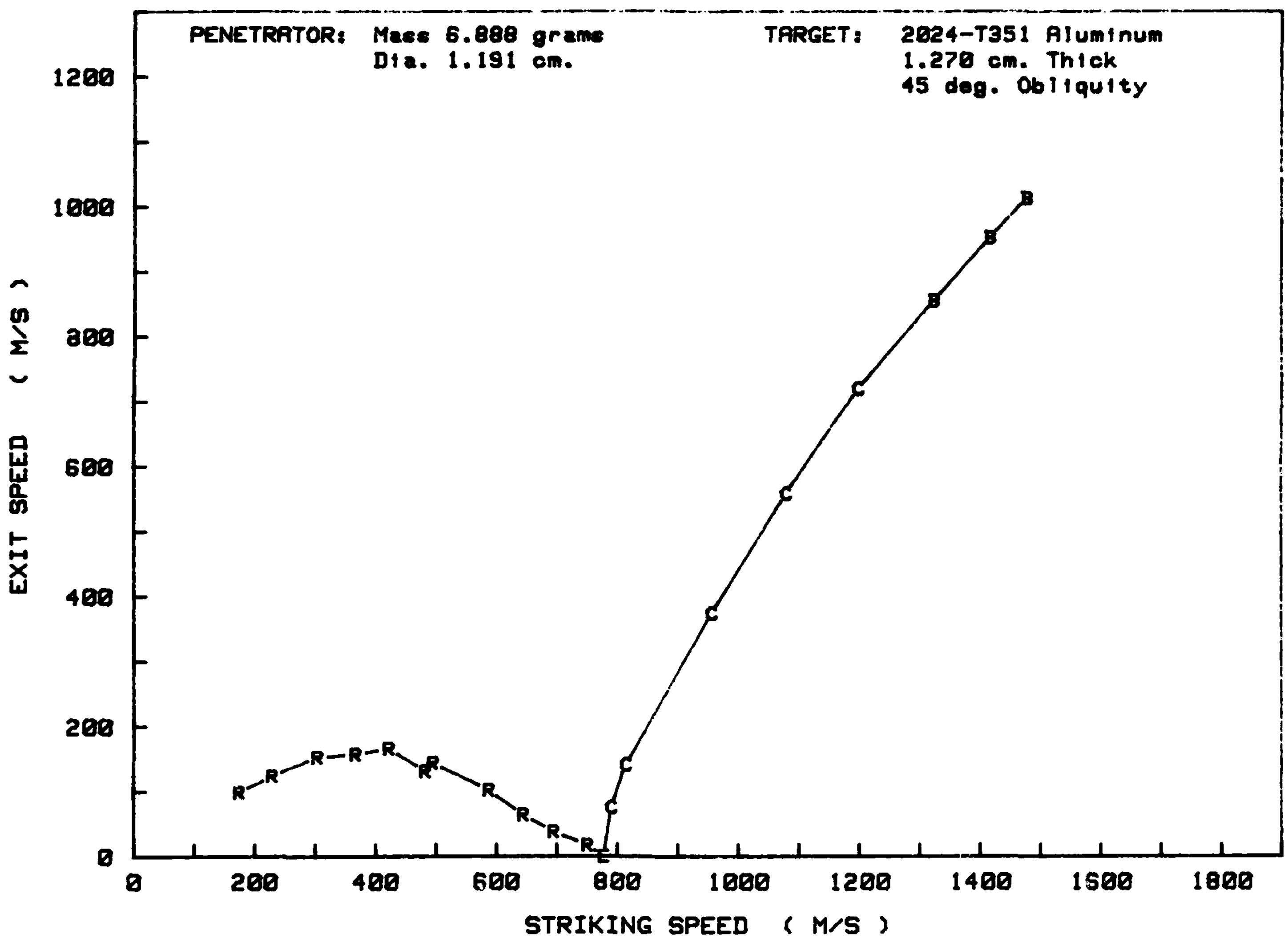


Figure 13a 15/32 in. Steel Sphere Impacting 1/2 in. Thick Aluminum At 45 Degrees
(Exit Speed As A Function Of Striking Speed)

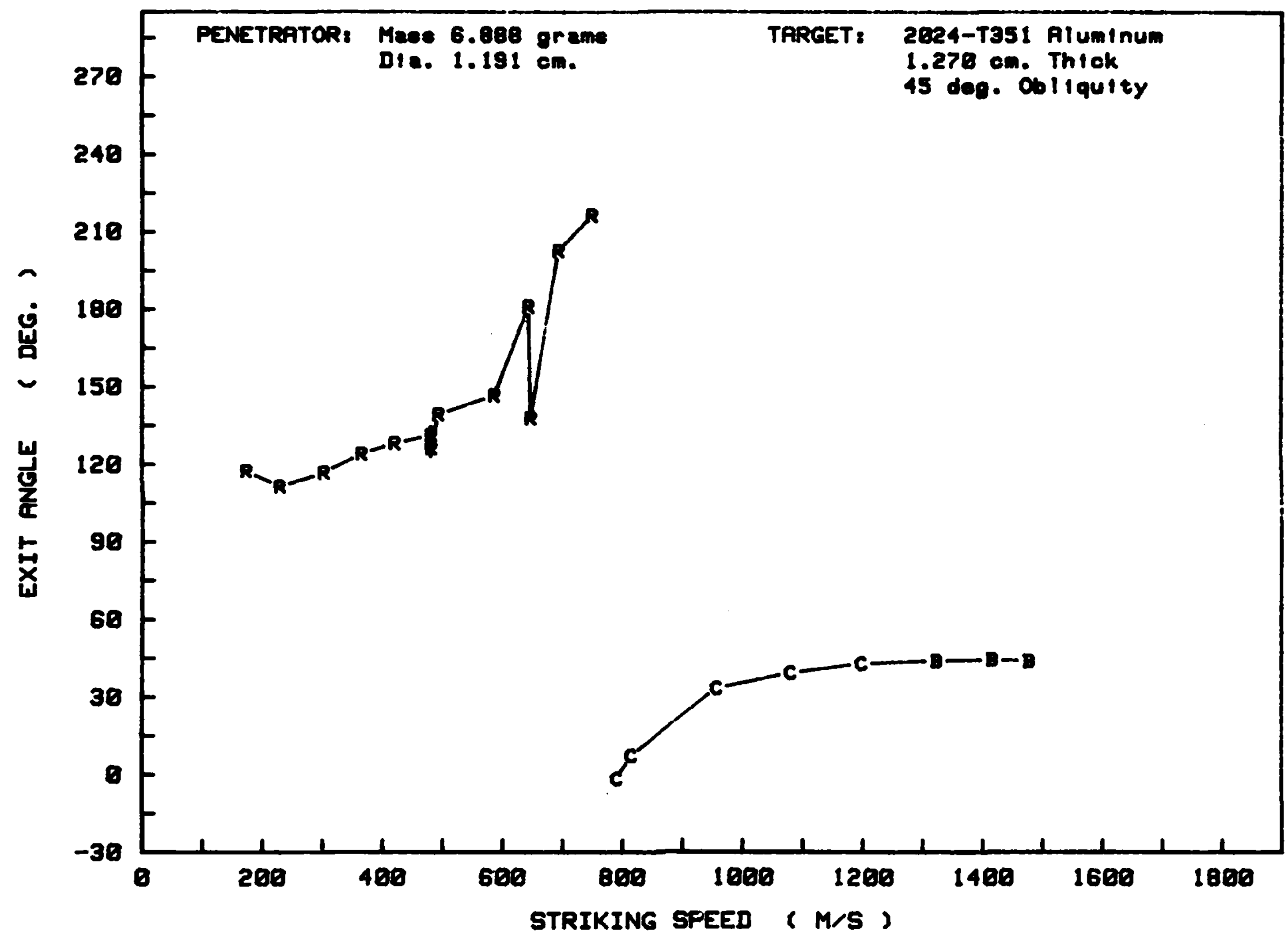


Figure 13b 15/32 in. Steel Sphere Impacting 1/2 in. Thick Aluminum At 45 Degrees
(Exit Angle As A Function Of Striking Speed)

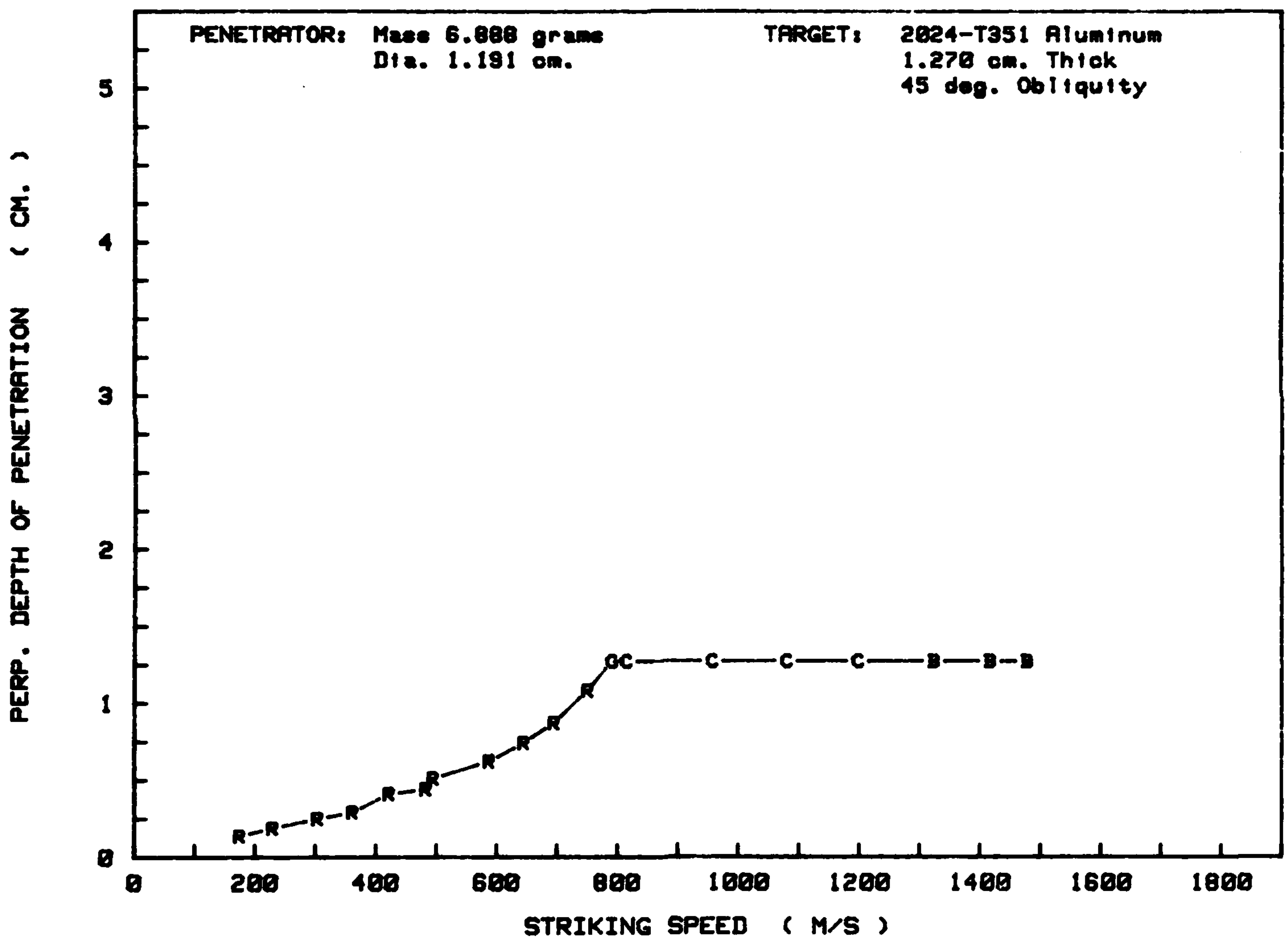


Figure 13c 15/32 in. Steel Sphere Impacting 1/2 in. Thick Aluminum At 45 Degrees
(Perpendicular Depth As A Function Of Striking Speed)

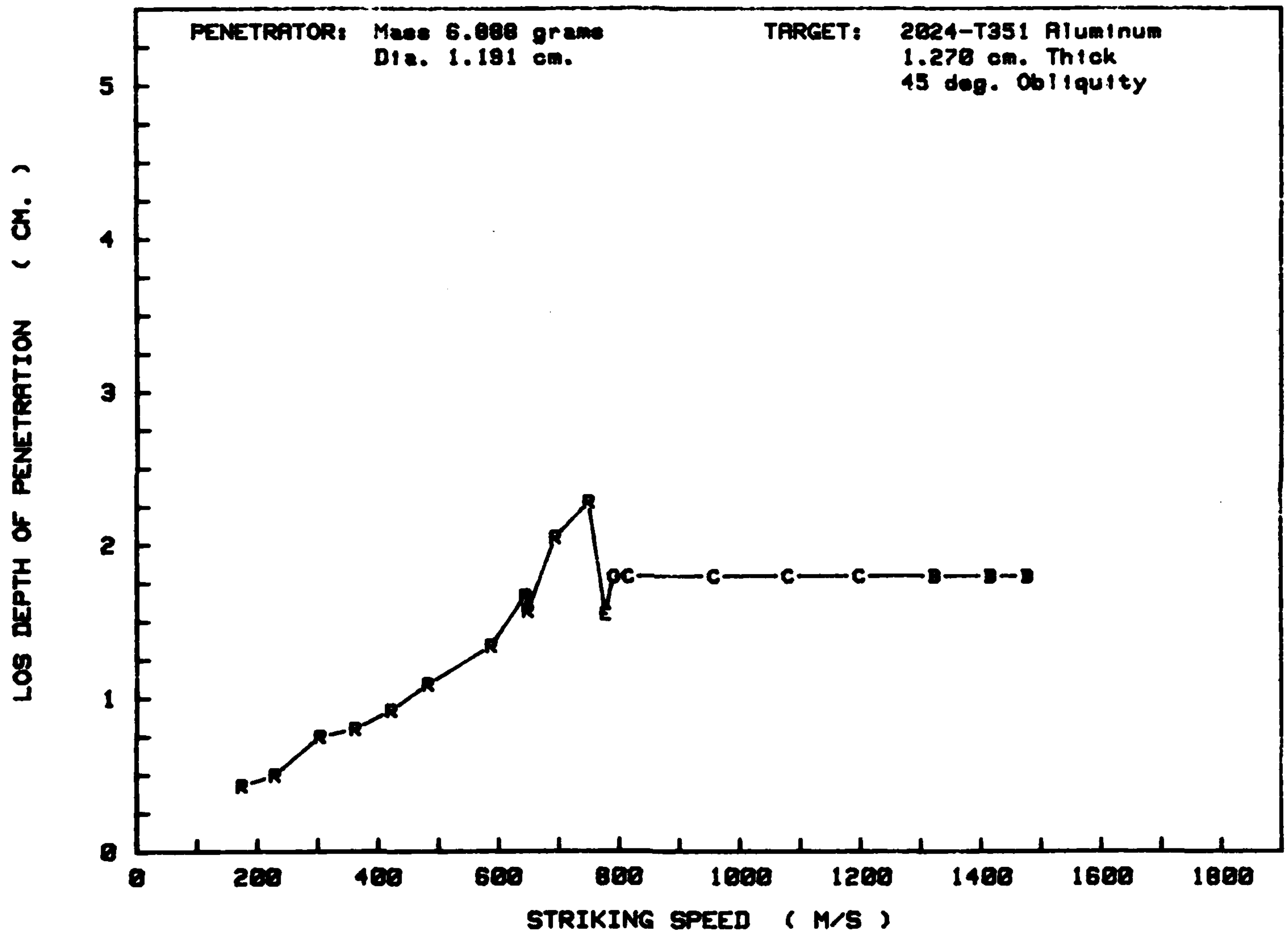


Figure 13d 15/32 in. Steel Sphere Impacting 1/2 in. Thick Aluminum At 45 Degrees
(Line-of-Sight Depth As A Function Of Striking Speed)

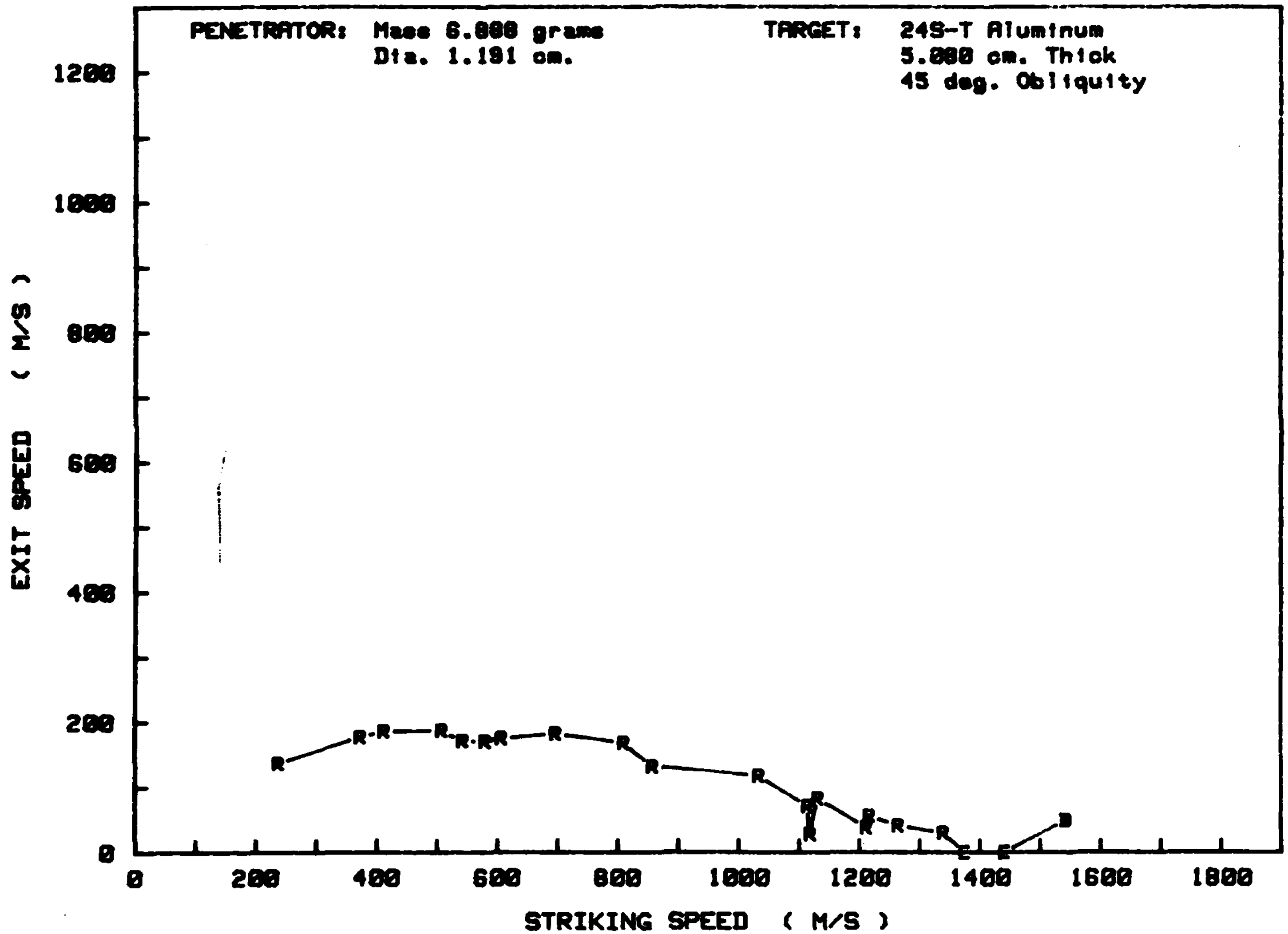


Figure 14a 15/32 in. Steel Sphere Impacting 2 in. Thick Aluminum At 45 Degrees
(Exit Speed As A Function Of Striking Speed)

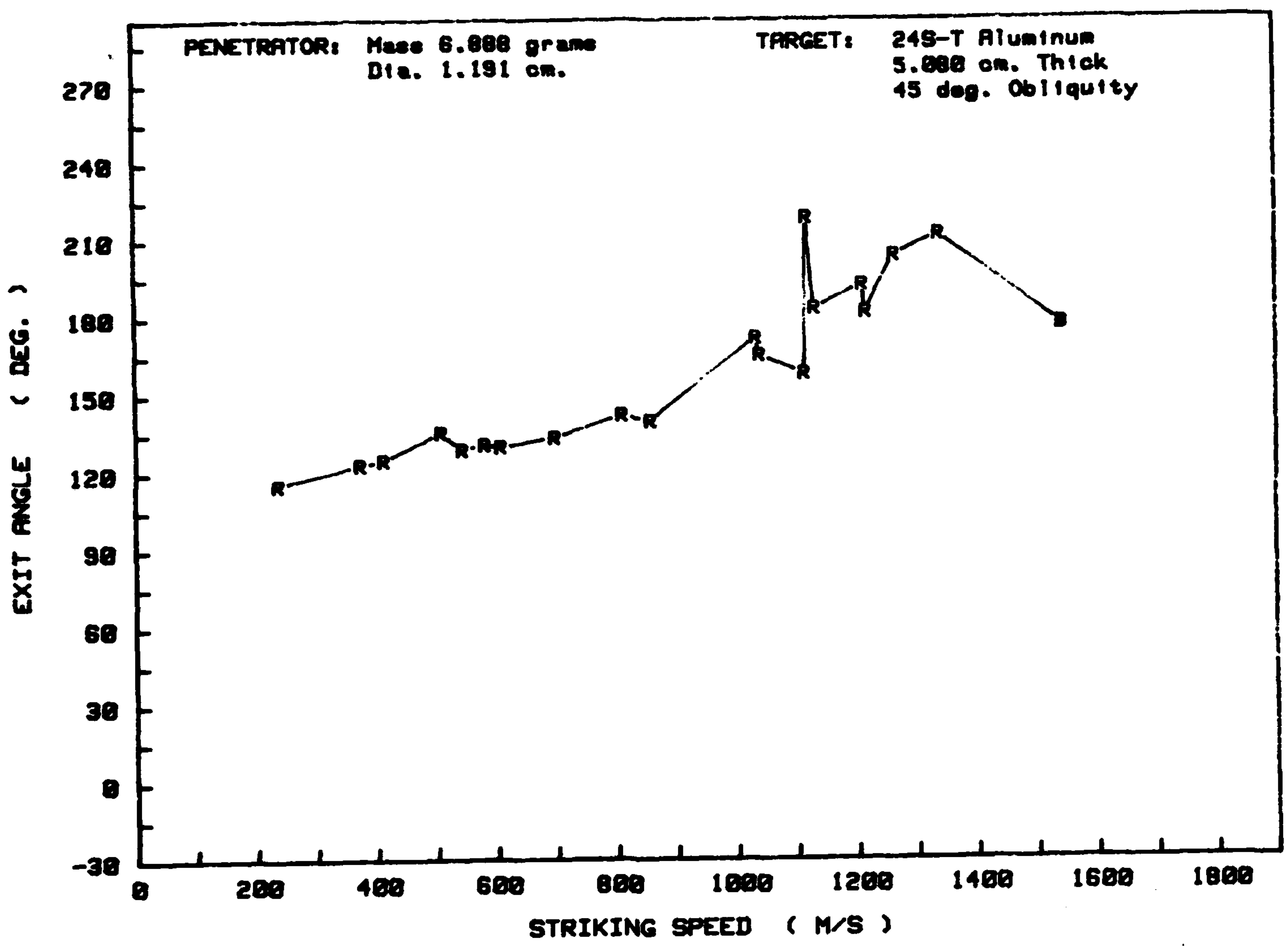


Figure 14b 15/32 in. Steel Sphere Impacting 2 in. Thick Aluminum At 45 Degrees
(Exit Angle As A Function Of Striking Speed)

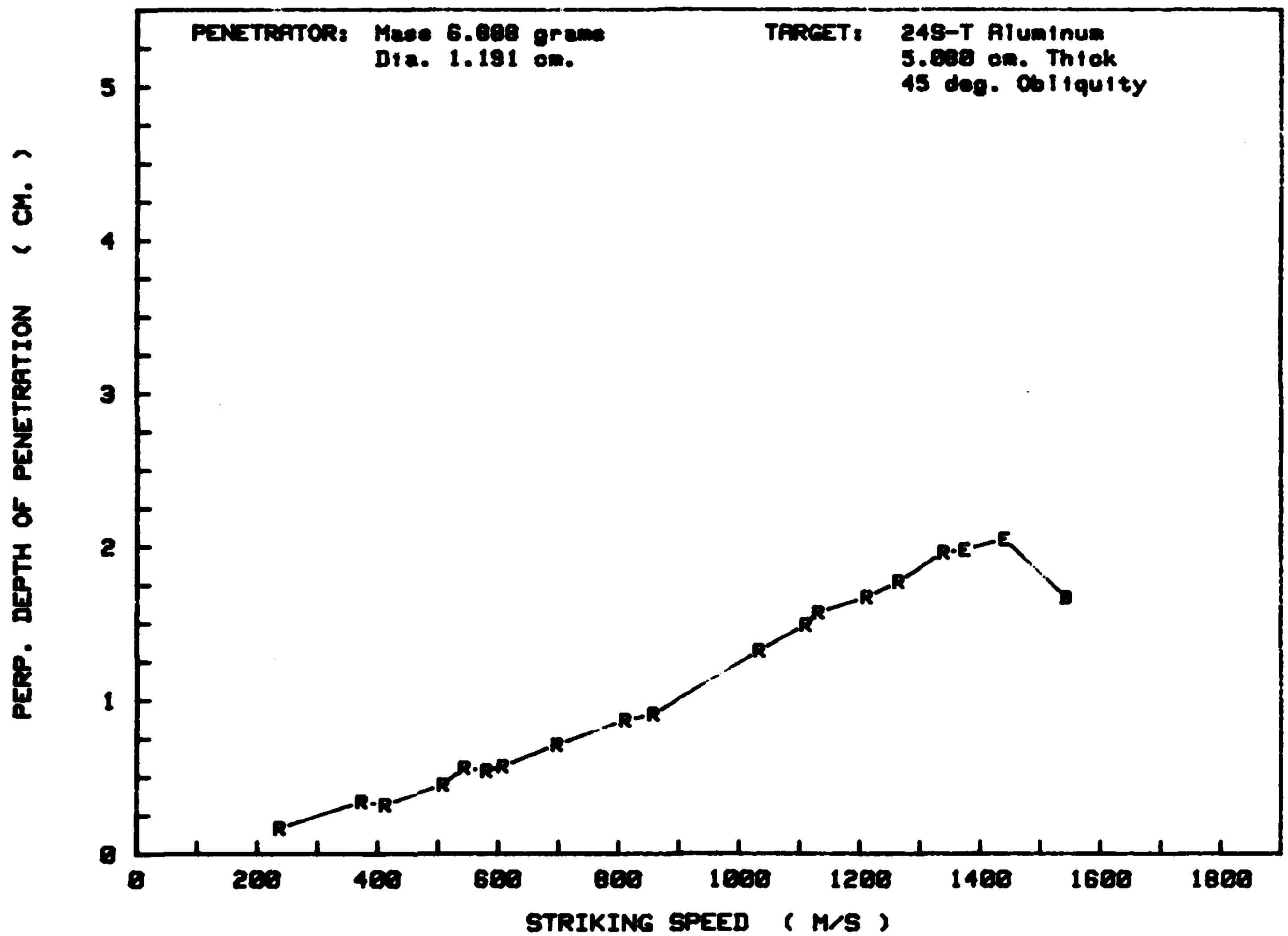


Figure 14c 15/32 in. Steel Sphere Impacting 2 in. Thick Aluminum At 45 Degrees
(Perpendicular Depth As A Function Of Striking Speed)

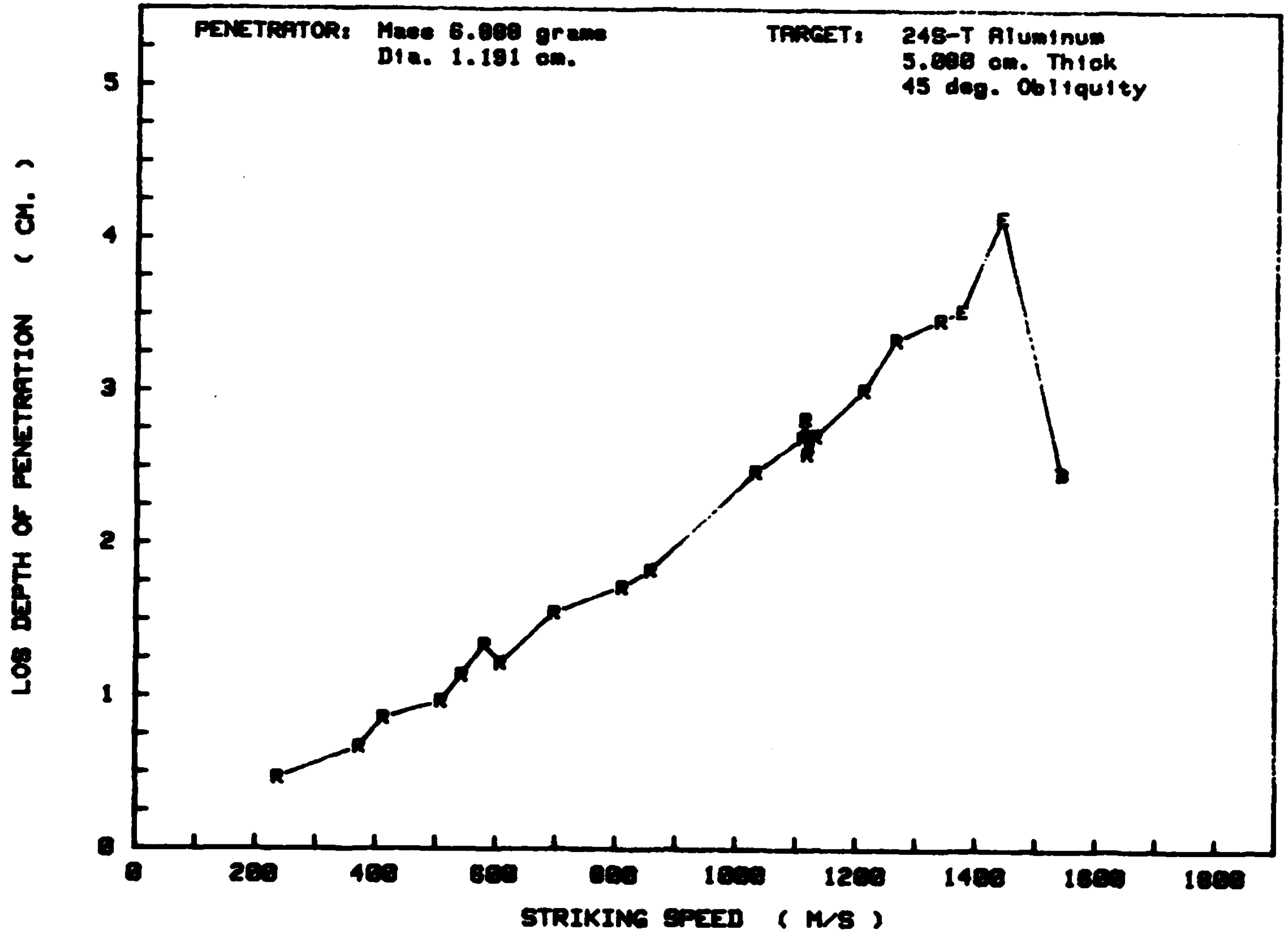


Figure 14d 15/32 in. Steel Sphere Impacting 2 in. Thick Aluminum At 45 Degrees
(Line-of-Sight Depth As A Function Of Striking Speed)

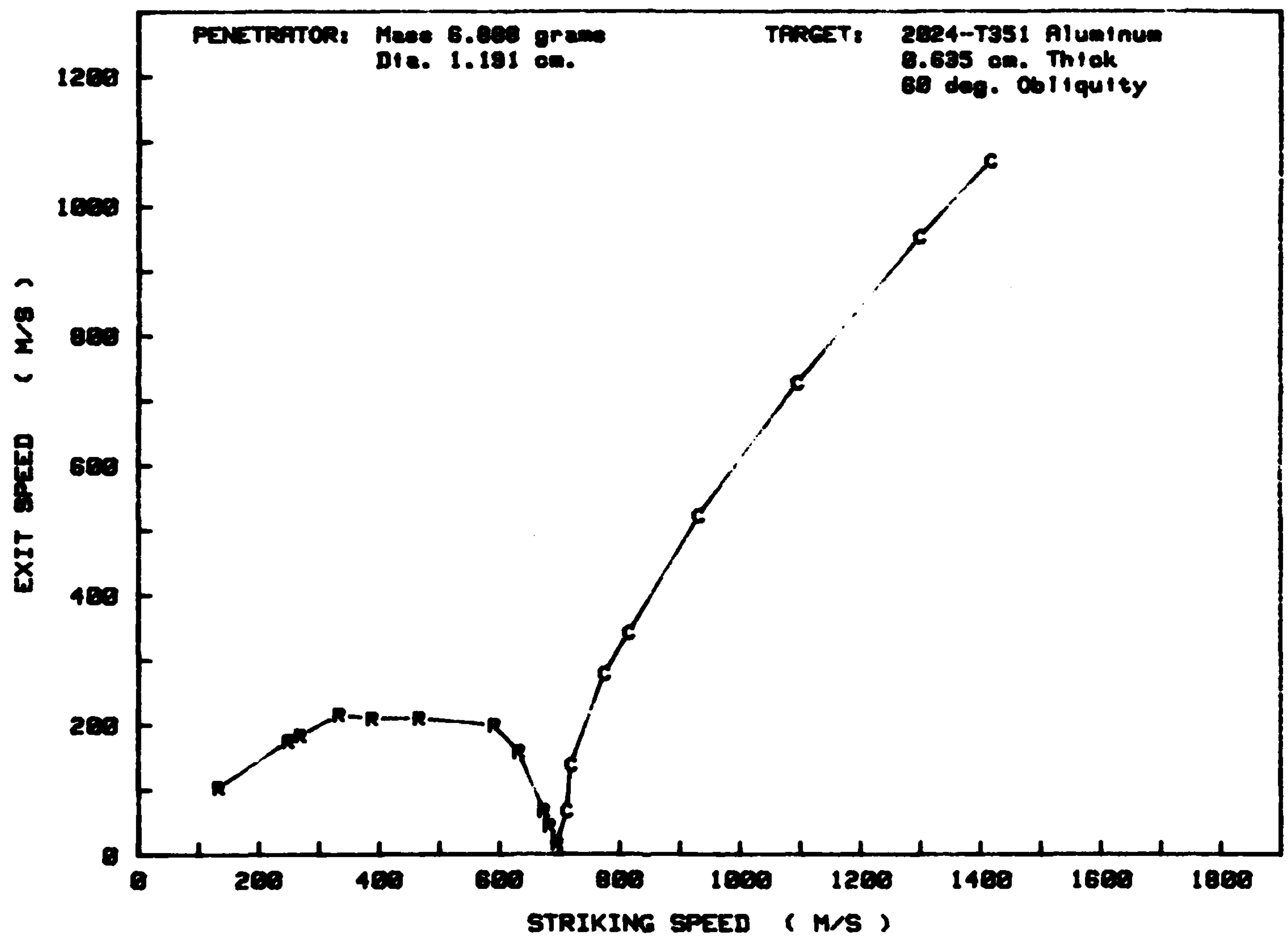


Figure 15a 15/32 in. Steel Sphere Impacting 1/4 in. Thick Aluminum At 60 Degrees
(Exit Speed As A Function Of Striking Speed)

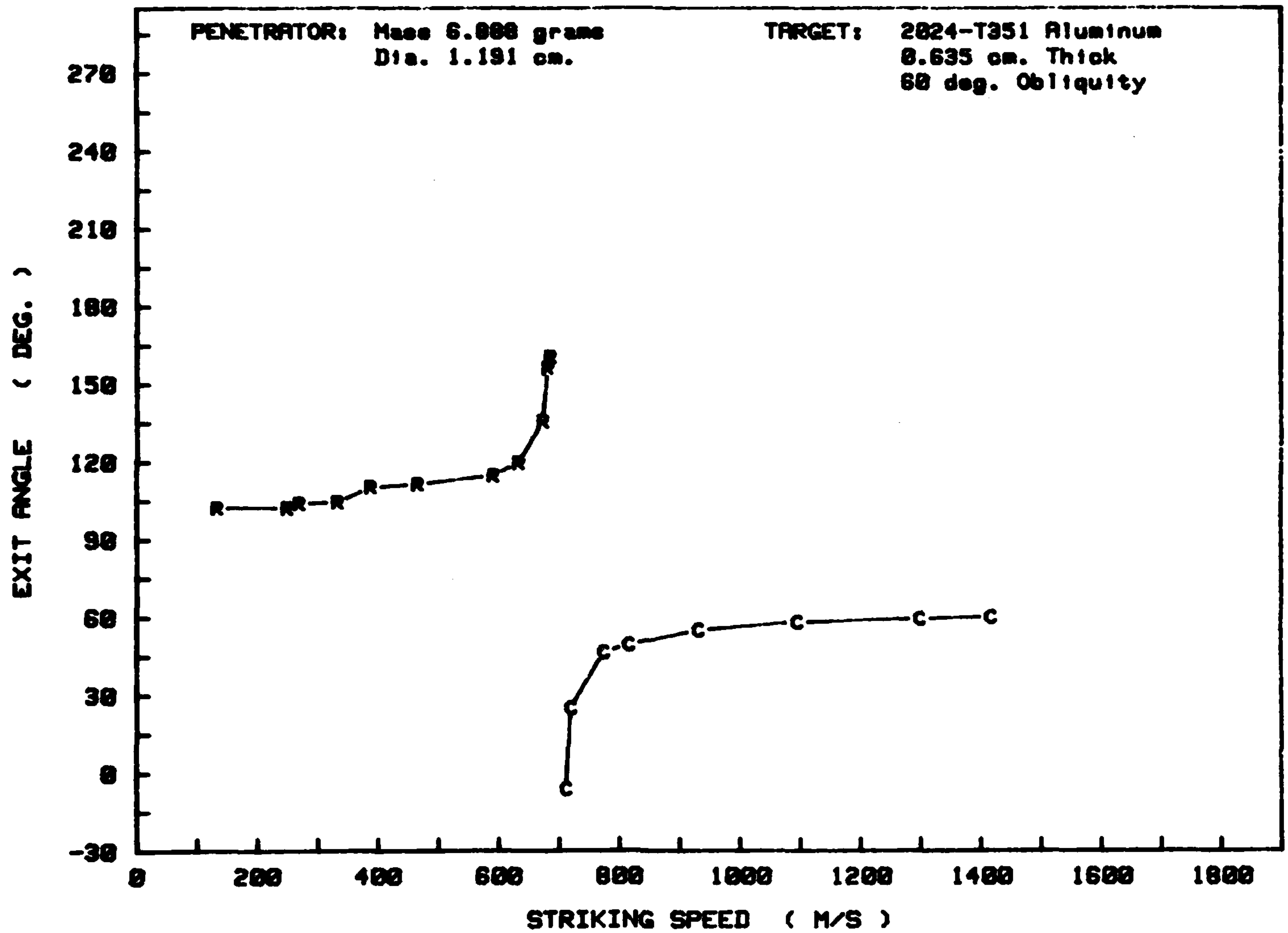


Figure 15b 15/32 in. Steel Sphere Impacting 1/4 in. Thick Aluminum At 60 Degrees
(Exit Angle As A Function Of Striking Speed)

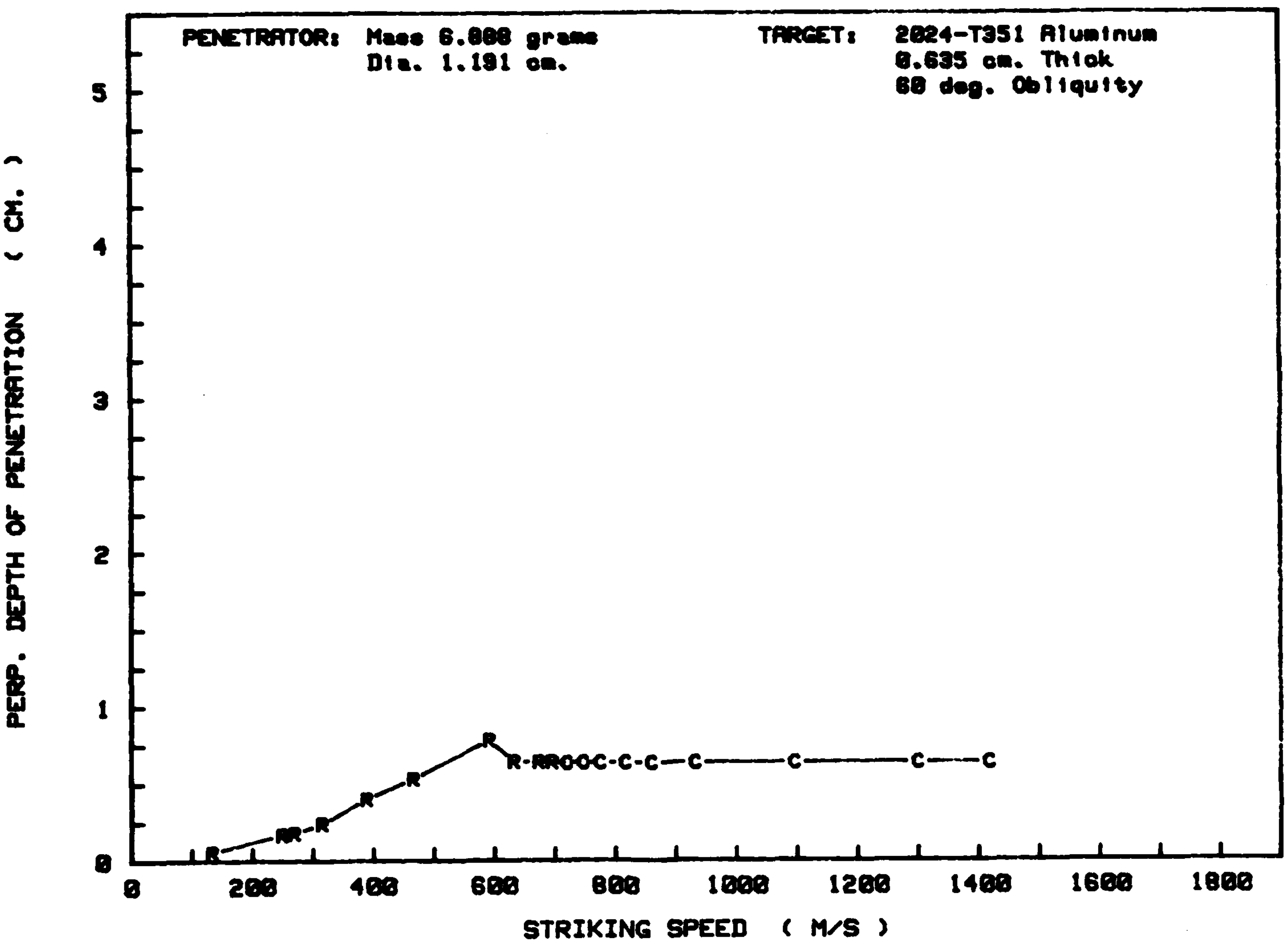


Figure 15c 15/32 in. Steel Sphere Impacting 1/4 in. Thick Aluminum At 60 Degrees
(Perpendicular Depth As A Function Of Striking Speed)

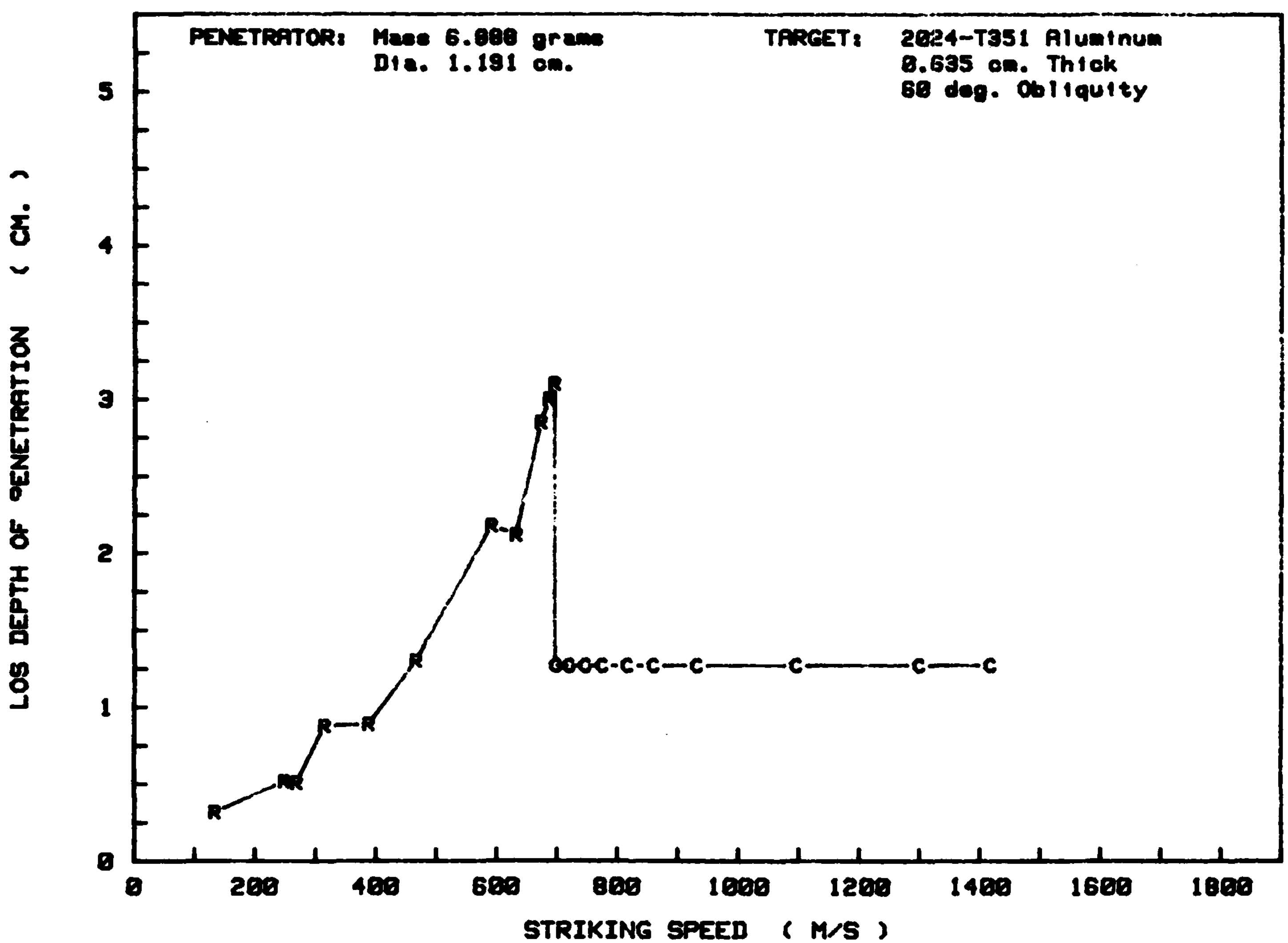


Figure 15d 15/32 in. Steel Sphere Impacting 1/4 in. Thick Aluminum At 60 Degrees
(Line-of-Sight Depth As A Function Of Striking Speed)

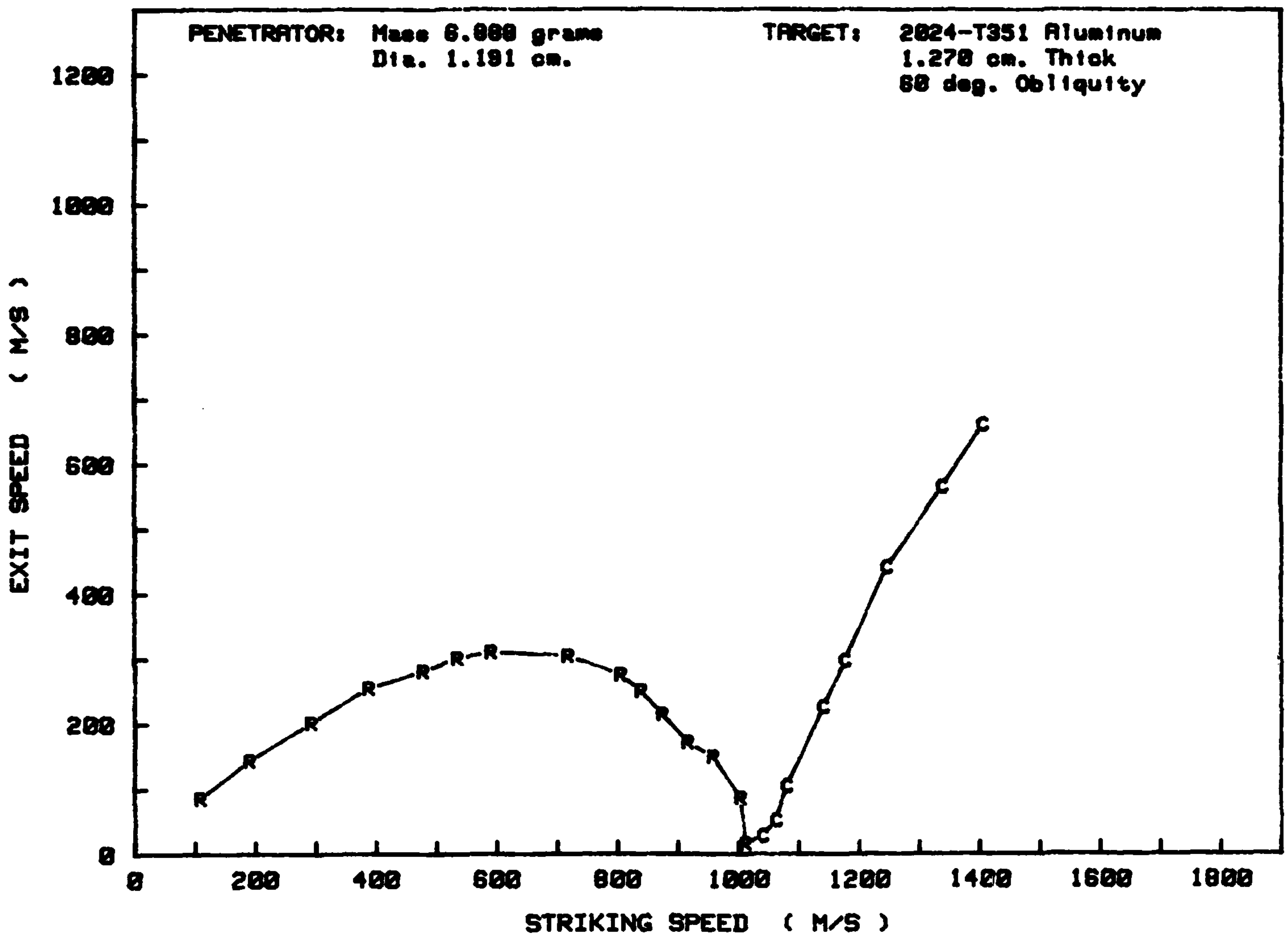


Figure 16a 15/32 in. Steel Sphere Impacting 1/2 in. Thick Aluminum At 60 Degrees
(Exit Speed As A Function Of Striking Speed)

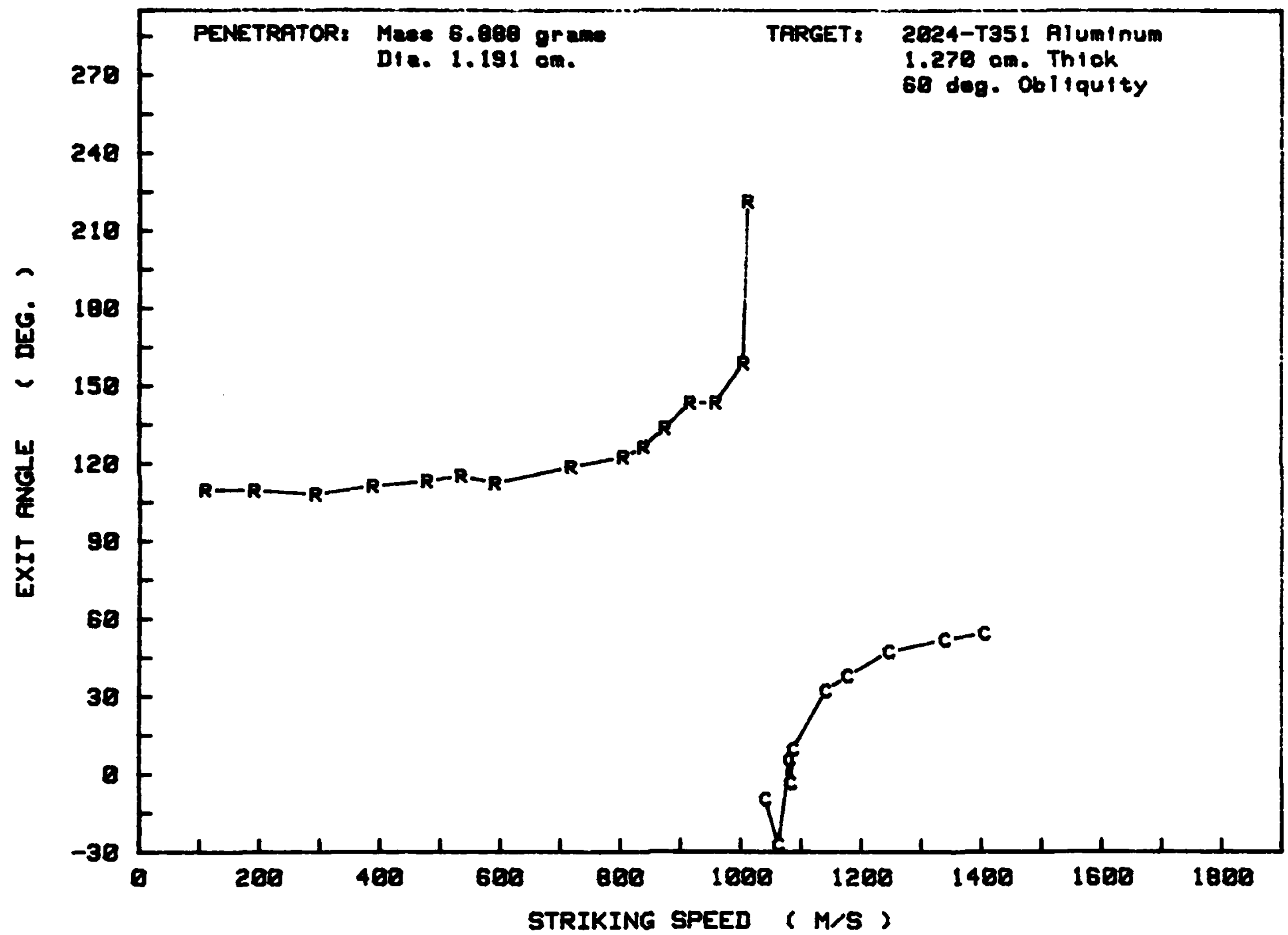


Figure 16b 15/32 in. Steel Sphere Impacting 1/2 in. Thick Aluminum At 60 Degrees
(Exit Angle As A Function Of Striking Speed)

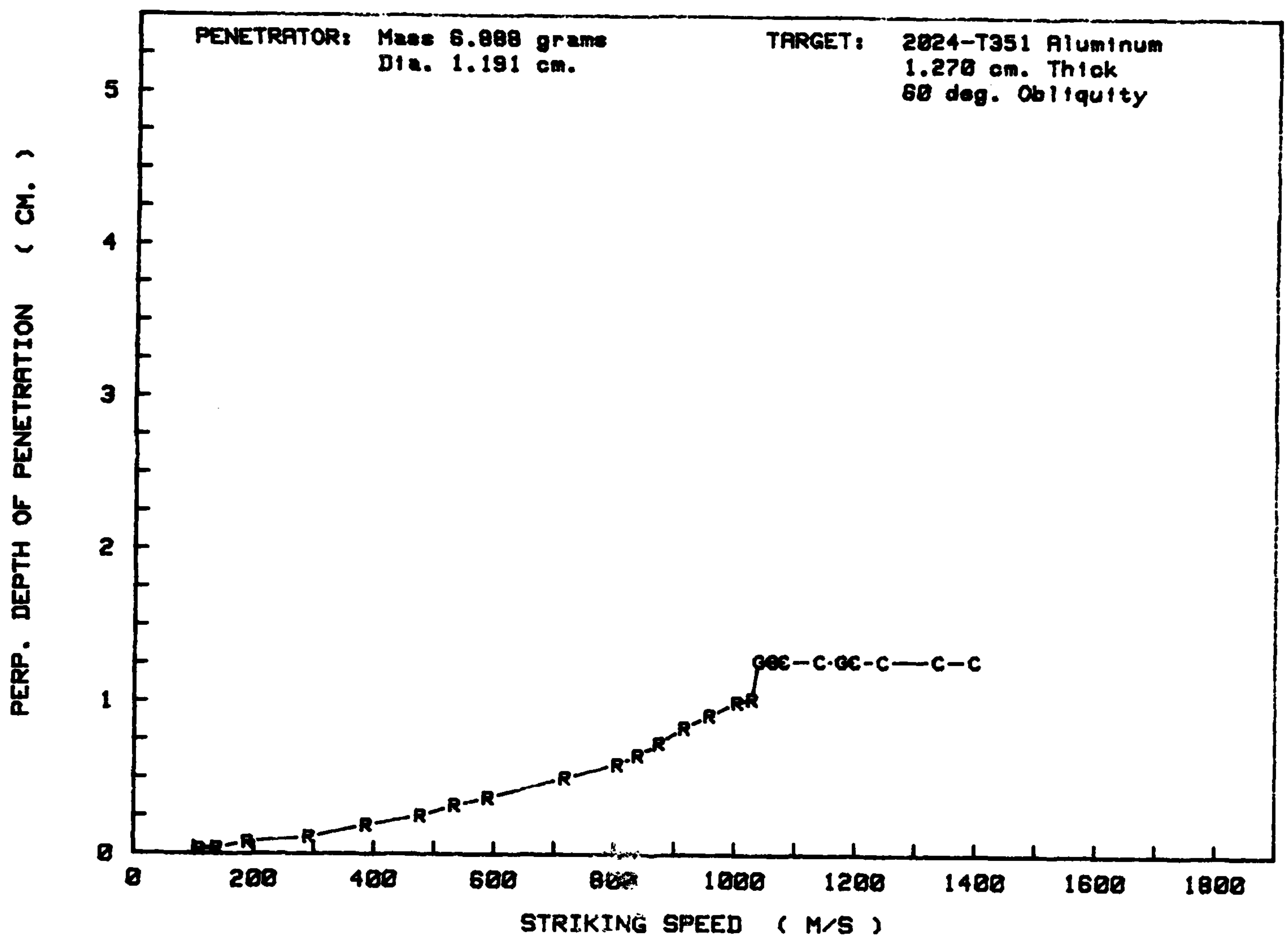


Figure 16c 15/32 in. Steel Sphere Impacting 1/2 in. Thick Aluminum At 60 Degrees
(Perpendicular Depth As A Function Of Striking Speed)

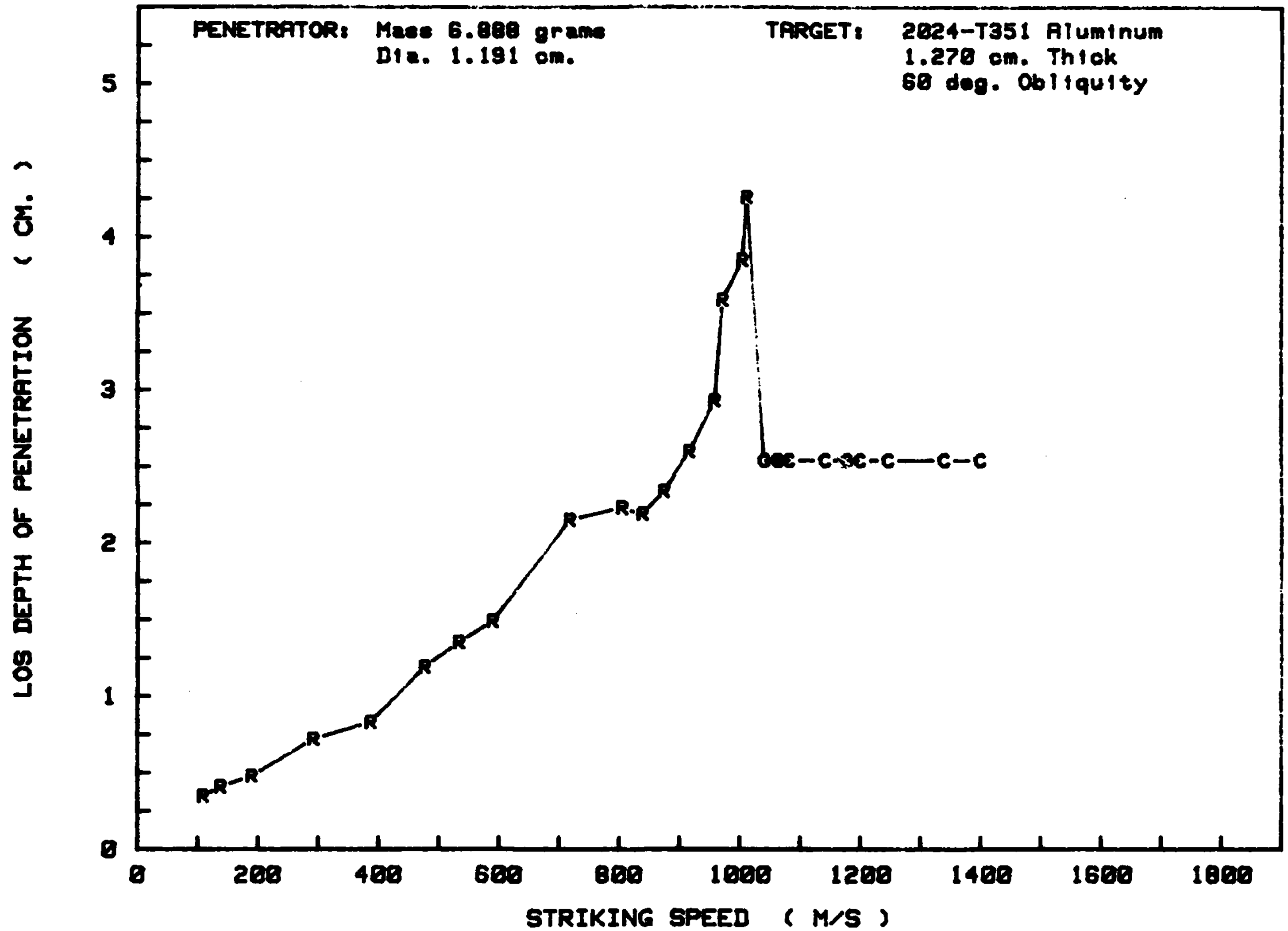


Figure 16d 15/32 in. Steel Sphere Impacting 1/2 in. Thick Aluminum At 60 Degrees
(Line-of-Sight Depth As A Function Of Striking Speed)

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